PHILOSOPHICAL TRANSACTIONS.

I. *On the Organization of the Fossil Plants of the Coal-Measures.*—Part XIX.

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[Plates 1–9.]

In the year 1832 the late Rev. Wm. Vernon Harcourt obtained an important fragment of a Lepidodendroid branch from a colliery at Hesley Heath, near Rothbury, in Northumberland. It was the first example seen of such a *Lepidodendron* in which much of the external organization was preserved, hence it naturally excited great interest. Probably no other fossil has ever obtained a wider notoriety. The specimen was first figured and described by Witham, of Lartington, then by the authors of the 'Fossil Flora of Great Britain,' and finally by the late Adolphe Brongniart. Witham gave to the specimen the name of *Lepidodendron Harcourtii*, after its discoverer, which name it has ever since borne; but his accompanying description was full of errors. Lindley and Hutton were not much more successful in their subsequent attempts to interpret the specimen. It was otherwise when Brongniart received a section of the fragment from Hutton, which he submitted to a very elaborate investigation. The specimen was not a perfect one. The outer cortex and leaves were wholly wanting; but the rest of its organization enabled Brongniart to base upon it the construction of a diagrammatic figure of the plant when living; this he believed would prove to be typical of that of the entire Lepidodendroid family. His pre-eminent position as a palæobotanist caused his views to be universally accepted. Brongniart's typical *Lepidodendron* contained in its interior a single vascular cylinder, enclosing a medulla, from the exterior of which cylinder the leaf-traces received their vascular elements. Later in life two fragments belonging to different plants were obtained by him, in each of which there existed the central cylinder seen

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in *Lepidodendron Harcourtii;* but in both cases this cylinder, which he had designated *étui médullaire,* or equivalent of the protoxylem or medullary sheaf of recent exogenous stems, was surrounded by a secondary zone of wood, developed exogenously through the instrumentality of a cambium layer. BRONGNIART was unfortunately biassed by the fact that no such secondary growth existed amongst living Cryptogams—to which group he correctly determined the *Lepidodendra* to belong. The existence of a secondary, exogenously-developed, vascular zone was a clear proof in his eyes that his new plants could not be Cryptogams; hence he referred them to the family of Gymnosperms, and connected them with the well-known Carboniferous plants called *Sigillariæ.*

The conclusions thus arrived at by the great French palæontologist were almost universally accepted at the time when I began my investigations into these subjects, some thirty years ago; I soon obtained clear proofs that many of the Carboniferous Cryptogams, unlike their living representatives, were provided with a secondary, exogenously-developed, vascular zone. That this is the case with most of BRONGNIART'S *Lepidodendra* is now an almost universally accepted fact. But these plants vary in a very remarkable manner as to the stage of growth at which this secondary development makes its appearance. In some, like the *L. selaginoides,* it exists in very young twigs. In others, like the Arran plant (*L. Wunschianum,* WILL.), the branches have to attain to very large, even arborescent, dimensions, before the smallest trace of such a growth is discoverable. The *L. Harcourtii* is one of those in which no exogenous zone has yet been observed; but the history of the Arran plant teaches us to be cautious ere we conclude that it never develops such a zone of secondary xylem. The largest branch of *L. Harcourtii* yet met with is $3\frac{1}{2}$ inches in diameter, apart from its leaves. I have specimens of the Arran plant of yet larger size, equally devoid of all traces of secondary xylem; but when we come to stems of the latter plant 2 feet in diameter, we find in them the most magnificent examples of a secondary zone of wood that I have yet met with. This fact has only become known to us through a rare and fortunate accident. We find in our Coal-Measures very many, even large, Lepidodendroid and Sigillarian Trees, but unfortunately these are all mere casts of the outer surface of the cortex, each interior being only a mass of inorganic clay or sand. Hence we know nothing of what the internal organization of these arborescent forms was. But the Arran stems have been preserved for us under very different conditions. They have been imbedded, not in sand and mud like those ordinarily met with, but in volcanic ash. Their central vascular axes, with their contained medullæ, are as perfect as they were in the living plants. Not only so, but much of their cortex is equally well preserved. But for this happy and unique circumstance, we should have been entirely ignorant of the fact that a *Lepidodendron* might attain to a considerable magnitude without any trace of a secondary vascular zone making its appearance in its stem, and yet, ere it attained to its ultimate dimensions of a noble forest tree, it contained such a zone. Having,

however, learnt this indisputable truth, we must admit that, though no branch of *L. Harcourtii* has yet been found possessing a secondary xylem, it would be presumptuous to deny the possibility that, if we could discover its matured stems, as we have done those of the Arran trees, corresponding results would follow. This conclusion becomes the more probable when we remember how very few there are, even of the smaller *Lepidodendra,* which have not developed a secondary xylem. The only exceptional cases that I am acquainted with are two or three of which we only know the young twigs.

I had been working at my subject for many years before I obtained a specimen of the true *L. Harcourtii.* I found some very young branches of a *Lepidodendron* which I thought might represent an early state of BRONGNIART'S plant. I had long been anxious to see HARCOURT'S original specimen, for which I searched in vain the museums of York and Newcastle ; I at length succeeded in discovering it in the former place. The authorities of the museum kindly allowed me to make a section from it ; and thus provided with an indisputable type and specimen, I had ho difficulty in concluding that no one of the plants which I had studied and described in my Memoirs was a true *L. Harcourtii.* Additional examples of the plant from the Lancashire and Yorkshire deposits were soon afterwards added to my Cabinet. Thus armed, I wrote a note to the Royal Society,* in which I pointed out some of the most conspicuous characteristics of the type, and gave to the other form which I had confounded with it the name of *L. fuliginosum.*

Being now in possession of a number of additional sections of this classic plant, I was in a position to add much to previous accounts of it. Some of the specimens being much smaller and younger, whilst others are larger and older, than those in the hands of my predecessors in the study, I am able to fill up numerous lacunæ in our knowledge of the species.† In most of these examples the outermost cortical tissues and their remarkable foliar appendages are in a perfect state of preservation. For these latter valuable additions to my Cabinets I am once more indebted to my esteemed auxiliary, Mr. LOMAX, of Radcliffe, who, after finding the specimens at Dulesgate, kindly cut them into numerous sections in such directions as seemed to me most likely to reveal the entire structure of the plant.

Plate 1, fig. 1, represents a transverse section of the smallest branch I have

* 'Proceedings,' vol. 42, 1887.

† Three sections from different specimens of the plant have recently been investigated with great minuteness of detail by my friends Professor BERTRAND, of Lille, and M. HOVELACQUE. The results obtained by them are recorded in a Memoir by M. BERTRAND, published in the 'Travaux et Mémoires des Facultés de Lille,' entitled "Remarques sur le *Lepidodendron Harcourtii* de WITHAM," 1891. Though unable to accept all the conclusions arrived at by my colleagues, they have called my attention to several important points in the minuter details of the organization of the plant. Several of those points had already been detected by me, the figures of them drawn, and the descriptions written before I had received from Professor BERTRAND, or seen, a copy of his valuable Memoir. Unfortunately, the three sections obtained by my friends were equally imperfect with those of HARCOURT and WITHAM in having lost all traces of their outer cortex and its appendages.

hitherto seen (C. N. 1596 A.).* The diameter, including its leaves, is ·75 of an inch. Its medulla, *a*, is about ·06, and the vascular cylinder *b*, surrounding the medulla, is ·15.†

On two previous occasions‡ I have pointed out that the cells of the medullæ of some *Lepidodendra* appear to have occasionally assumed an extremely active meristemic condition. These examples I now know belong to *L. Harcourtii*. The peripheral cells of fig. 1 are somewhat larger than the more central ones; and many of both have also undergone secondary meristemic subdivisions. Hence whatever may be its physiological significance, the not unfrequent recurrence of such an active meristemic condition of the medullary cells of *L. Harcourtii* is a fact that must be accepted. Is it possible to accept this truth without admitting the correlate one that a medulla, the cells of which were from time to time so extensively multiplied in number, must simultaneously have undergone a corresponding increase of its diameter, and that such an enlargement would inevitably involve a similar increase in the diameter of its investing primary tracheal cylinder? Accurate measurements of these central organs at various stages of the plant's growth became important in their bearing upon this question. The radial thickness of the primary cylinder of fig. 1 from its medullary to its cortical border averages about ·02, and the number of tracheæ counted radially between these borders, including the small peripheral ones, does not exceed from three to seven.

In vertical sections the cells of the medulla are constantly arranged in vertical lines, alike in young and older branches. They correspond in this respect with the similar organs of ferns to which DE BARY so unhesitatingly applied the name of a medulla.

Professor BERTRAND, of Lille, has recently described the details of the periphery of the primary tracheal cylinder, to which he gives the name of Corona. Though I am unable to accept all the detailed conclusions at which he has arrived, it must be

* I have more recently obtained a yet smaller example, the diameter of which, including its leaves, is only ·55; that of its medulla is ·02, and of its primary tracheal cylinder ·055.

† It is extremely desirable that we should endeavour to adopt some common nomenclature for the characteristic organs of these plants. M. BRONGNIART applied to the vascular cylinder just referred to the name of "Etui Médullaire." In the recent translation of SOLMS LAUBACH'S 'Fossil Botany,' the same cylinder, including what I regard as its enclosed medulla, is designated the *Central Xylem Strand*. We may approximate to a common terminology if we adopt this nomenclature for the central axis. We have the authority of the late Professor DE BARY for designating its central parenchyma a *Medulla*, may recognise its investing vascular tube as the *Primary Tracheal*[a] *Cylinder*, and term the exogenous structure which is so often developed yet more externally, as the *Secondary Xylem Strand*. At all events this is the nomenclature that I shall henceforth apply to these several structures. The divisions of the cortex require further consideration.

‡ Memoir XVI., Plate 5, fig. 26A, 'Phil. Trans.,' 1889, and Memoir XII., Plate 33, fig. 20, 'Phil. Trans.,' part 2, 1883.

[a] Throughout this Memoir I employ the term tracheæ in the comprehensive sense suggested by Professor DE BARY, in his 'Comparative Anatomy of the Phanerogamous Ferns;' see English Translation, p. 155.

admitted that he has done good service in directing attention to the careful study of this Corona. In his figure of the structure in question,* BRONGNIART represents it as consisting of a peripheral line of festooned loops, each one of which encloses the transverse section of the tracheæ of a leaf-trace. Each of these "festons," as he calls them, appears as if composed of small tracheæ, like those occupying the entire periphery of the primary tracheal cylinder. But none of my numerous sections, including one which, like BRONGNIART'S, is from HARCOURT'S original specimen, correspond in this respect with BRONGNIART'S figure. As will be seen shortly, the true structure of this part of the primary tracheal cylinder is accurately represented in my Plate 2, fig. 5: which figure is taken, not from BRONGNIART'S original, but from another section in my Cabinet (C. N. 381) identical in every feature with that studied by BRONGNIART, though in a much finer state of preservation.† In my figure we see transverse sections of a number of vascular projections, *e*, of somewhat varied forms, alternating with many small crescentic bays, not loops, in each one of which is located the transverse section, *c*, of a leaf-trace.‡ But in the young specimens now under consideration these peculiar projections are scarcely visible. Their condition is represented in Plate 3, fig. 6, which is a faithful transcript of a part of one of these cylinders from the section in my Cabinet, 380*a*. Here we find that the already liberated leaf-trace bundles, *c'*, of fig. 5, are much more prominent objects than the projections, *c*, of the same figure.§

Before tracing the further course of these foliar bundles we must consider the condition of the cortex in these young branches. One special fact connected with an individual bundle of fig. 1 will be referred to later on.

Immediately investing, and in contact with, the periphery of the primary tracheal cylinder, we have clear evidence of an extremely delicate thin-walled parenchymatous tissue, which will be again considered on describing some vertical sections of these young twigs. External to this delicate zone we have now a vacant area, *c*, from which nearly every trace of structure has disappeared. Here and there are indications that it was occupied by an outward extension of the delicate parenchyma already described; this merged gradually into the innermost portion of the next more external cortical zone, *d*. The breadth of this vacant area is about ·1.

In his restoration of *L. Harcourtii*, M. BRONGNIART indicated that the boundary line between the cortex that once occupied the space *c*, and the well preserved tissue *d*, *d'*, was a sharply defined one. This, however, is certainly not so. The

* 'Histoire des Végétaux Fossiles,' vol. 2, p. 20, fig. 6B.

† I find an equally accurate figure in BERTRAND'S Memoir, 'Remarques sur le *Lepidodendron Harcourtii* de WITHAM,' Plate 1, fig. 5.

‡ Messrs. HOVELACQUE and BERTRAND alike refer to these projections, singly and in their combined forms, under the names of "*poles*" and "*pointements*," whilst the section, *c'*, of the leaf-traces, they designate "*pièces sortantes*."

§ This circumstance seems to me to suggest that the "*pointements*" of M. BERTRAND are of much less importance to the development and separation of the leaf-trace bundle than from his Memoir he appears to regard as probable.

details of the structure of *d* will be best understood when we examine longitudinal sections of it. This zone appears in fig. 1 as composed of cells averaging about ·02 in diameter. They are mainly characterised by variations in the thickness of their cell-walls. In the innermost ones, *d*, the walls are extremely thin and colourless, but these cells pass very regularly into a thick walled series, *d'*, of a much darker brown tint. The diameter of this zone is about ·5. It is invested by a very similar zone of about the same thickness, but in which the cells are in a more disorganized state, yet the latter is a mere extension of the former one.

Externally to the preceding layers is a thin zone of radially arranged elements, small portions of which were preserved at some peripheral points of HARCOURT'S specimens, and which were noticed, though misunderstood, alike by WITHAM, LINDLEY and HUTTON, and BRONGNIART. Very little was known about this curious zone until I published Part II. of my series of Memoirs in the 'Phil. Trans.,' when I called attention to its existence under the name of the *prosenchymatous layer* of the cortex of my *L. selaginoides*. In fig. 5 of BRONGNIART'S Plate 20, already referred to, he copied from the 'Fossil Flora of Great Britain,' a figure which its authors represented to be a longitudinal section through the tissue in question. This it certainly was not. In my Memoir just referred to I pointed out that in its developed condition this tissue was composed of cells which were "elongated vertically and, at last, pass rapidly into the almost vascular form of prosenchyma" (*loc. cit.*, p. 200, and Plate 24, fig. 1*i* and fig. 2*i*). On p. 211 of the above memoir I called attention to a copious development, in the same part of the cortex, of a similar prosenchyma (*loc. cit.*, Plate 27, fig. 29*d*); and again at p. 213 of the same publication I showed the existence of an identical structure in a Syringodendroid form of *Sigillaria*, belonging "to the group of *S. Saullii*, *Schlothemii*, and *Scutellata*."

At a much later period (1881), in my Part XI., I not only again directed attention to the existence of this cortical prosenchymatous zone, but I now announced my observation that its radially arranged cells (Plate 51, fig. 2*f*) were generated at an undulating circular line which constituted the external border of the zone, the whole being primarily derived from a thin cellular layer of the cortex interposed between the leaf-cushions and the prosenchymatous zone. But my most complete notice of what appears to me to be the true history of the development of this tissue was only announced in 1887 in my Memoir on *Stigmaria ficoides*, published by the Palæontographical Society (pp. 18–22, figs. 22, 23, 24, and 24A). In this publication I demonstrated the existence of what I ventured to call a *bark-cambium* between the outermost cortex and its prosenchymatous zone, and through the meristemic actions of which additions were constantly made to the exterior of that zone, throughout the greater portion of the life of the plant; it being further evident that such copious thickenings of the cortex equally affected the aerial stems, the branches, and the Stigmarian roots. One fact more connected with this prosenchymatous zone is seen in the specimen represented by fig. 1. Its first development in young twigs does not advance simultaneously throughout the entire circle of the cortex. In the

example fig. 1*f* there is an arc, the chord of which is about ·5 of an inch in length, in which the zone has not yet made its appearance, whilst on the opposite side of the circle each radial line of the prosenchymatous cells contains fully a dozen of them. Outside this zone we have the outermost cortical zone, which we shall understand best by referring to my enlarged figures of some of these structures as seen in longitudinal sections.

In fig. 2 we have a segment of the cortex and leaves of fig. 1 enlarged eight diameters. Of the innermost cortex of the twig we here see no trace; but at *d* we find the more delicate cells of the inner half of the middle cortex. The innermost margin of this zone consists of oval cells arranged somewhat concentrically, their shorter axes being their radial ones. More externally, *d'*, they became more irregularly circular. In fig. 4 we have four radial lines belonging to the prosenchymatous zone, *e*, with the outermost cells of the middle cortex at *d*, and those of the outermost cortex at *f*. The breadth of this zone is about ·02; fig. 4 is enlarged about fifty diameters. The leaves must be considered separately.

Of the longitudinal aspects of the medulla and its investing primary tracheal cylinder there is little to be remarked beyond what we find common to most of the other *Lepidodendra*, viz., the barred structure, and the large size of the more internal tracheids, contrasted with the small diameters of the peripheral ones. I discover, also, in all these young twigs of *L. Harcourtii*, the condition previously noticed in *L. Wunschianum* and in *L. Mundum*.* The transverse bars of the tracheids are connected by innumerable very delicate vertical threads. I find no trace of these in vertical sections of my older branches of *L. Harcourtii*, where such threads are conspicuous in my Arran plant.

One other feature occurs here and there at the periphery of the primary tracheal cylinder, viz., the existence of vertical lines of a few barred cells. Two illustrations of these from the Cabinet specimen 1596D are given in Plate 1, figs. 2*a* and 2*b*. The mean vertical length of each cell is about ·025.

Vertical sections of the middle and other external structures of the cortex are shown in figs. 9 and 9A on Plate 2, enlarged four diameters, and still more definitely in fig. 10, which is enlarged fifteen times. We here see the delicate, thin-walled cells of the middle cortex *d*, passing into the more robust ones at *d'*. The elongated tubes of the prosenchymatous zone are conspicuous at *e*, whilst at *f* the thin layer of cells representing the outermost cortical parenchyma interposes between the zone *e* and the bases of the leaves *g*. In the vertical sections, as in the transverse ones, I not unfrequently find the zone *f* distinctly developed on one side, whilst little or no trace of it is visible in the cortex on the opposite side of the same section.

Fig. 3, Plate 1, represents a transverse section, natural size, of a very much larger stem from Airdrie in Scotland. Its mean diameter within the periphery of its prosenchymatous zone, the most definite boundary line for exact measurements, is about three inches. This is the largest stem or branch of *L. Harcourtii* that I have hitherto seen

* See Memoir XVI., Plate 5, fig. 14*a*, 'Phil. Trans.,' vol. 180, 1889.

or heard of. A lateral view of the entire specimen from which the section fig. 3 was cut is given in Plate 5, fig. 7. Its medulla *a* has a diameter of ·3, while that of fig. 1 is only ·06. The primary tracheal cylinder *b* has, in like manner, expanded from ·15 to ·5 of an inch. The mean radial thickness of this cylinder averages ·08, whilst that of fig. 1 was about ·02, and the approximate number of tracheæ that can be counted radially between the medullary and cortical margins of fig. 3 is twelve, contrasted with the five or six of fig. 1.* The arrangement of the peripheral tracheæ of this cylinder corresponds in all essential features with those of fig. 5, Plate 2. We find the leaf-traces, at *c'*, as in that figure, and the varied intervening prominences as at *e*; but all these peripheral features are rendered somewhat obscure by their being projected into a zone of dark-coloured, extremely delicate parenchyma, which has a radial thickness of about ·02. This, I presume, must be regarded as a phloem zone composed of soft bast, and identical with the "Liber" of M. BERTRAND. I cannot detect in it any trace of that author's "gaine protectrice," the equivalent of the bundle-sheath of English and German authors.

We now come to the zone *c*, from which all cellular structure has so frequently disappeared; but here, especially in the part to the right of the figure, between *c'* and *c''*, as well as at various other points within the area originally occupied by the inner cortex, we have definite evidence as to the structure of that tissue. It clearly consisted of an extremely delicate and, apparently, uniform parenchyma, which gradually passed, as I have already suggested, into that composing the innermost portion of the middle bark. With the exception of the latter fact, these conditions are in accordance with the views of BRONGNIART as shown at D, D, of his fig. 1, Plate 21.

The structure of the middle cortex, *d*, varies somewhat from that represented in my Plate 2, fig. 10, though there is less difference in the thickness of the cell-walls of the inner and outer cells, and there is a strong disposition in many of the former to arrange themselves in radial lines, whatever this may signify. Turning to the prosenchymatous zone, *e*, we see that it has undergone a large increase of radial thickness. What, to the naked eye, seems to represent its sharply-defined peripheral boundary really runs nearly through its centre. Outside that line we find a further extension of its radial rows of the square transverse sections of its prosenchymatous cells, giving a thickness to the entire zone of ·2. A conspicuous feature of this zone is its undulating course. At numerous points, as at *e'*, *e'*, it is projected outwards at a very acute angle, thus giving to its entire outline a crenulated aspect, the crenulations being directed inwards; and we further learn that at each of the projecting angles a leaf-trace has emerged, to reach a leaf. Why this leaf-trace cannot be seen in every one of these emergent points is easily understood by a fact of some importance to our comprehension of conditions observable in many of those arborescent stems which are imbedded in shales and sandstones, but retain little or no portion of their organized structure.

* These details may appear uninteresting, if not pedantic; but they have a very important bearing upon the problem of the growth and development of these branches.

Turning to Plate 5, fig. 7, we have a representation of one side of my stem (C. N. 380 X) from which the original of fig. 2 was cut. The face x, x corresponds to the peripheral arc of fig. 3 indicated by the same letters. That surfaces similar to that here exposed, having spiral series of vertically elongated conical protuberances, represent semi-decorticated *Lepidodendron* stems and branches has long been understood. Equally obvious was the probability that leaf-traces issued through each of these fusiform projections. But we were wholly devoid of information as to which special cortical zone these partially decorticated specimens represented.* The specimen, fig. 7, taken in connection with Plate 1, fig. 3, conclusively settles all these questions. Externally to the prosenchymatous zone we find here at f, f, in fig. 3, the usual thin outermost cortical layer of parenchyma supporting the leaf-cushions. Immediately within this, as at e', e', are the angular projections of the prosenchymatous zone, through several of which, as already observed, the leaf-traces can be seen emerging. The specimen demonstrates that these projecting angles are identical with the fusiform protuberances, f, between x and x of fig. 7, and we further learn that the surface in question represents the centre, or nearly so, of the prosenchymatous zone.

The Leaves.—No one has hitherto described any trace of these organs of *L. Harcourtii*. Now, however, we have them in abundance. But before examining the details of their structure, it may be well to follow the course of the leaf-traces from the points at which they leave the primary tracheal cylinder to those at which they enter the leaf-cushions.

During the last two years much attention has been given to the structure of Lepidodendroid leaves by Professor BERTRAND and by M. HOVELACQUE. In several of my previous Memoirs I have figured some conspicuous objects (*e.g.*, Memoir XI., Plate 47, g', g', g') which I mistook for large leaf-traces; but at p. 285 of the same Memoir I noted that "in each of the three leaves of fig. 1 in which this bundle appears there are peculiar condensations of the cellular tissue of the leaf." These observations are accurate, but, from the lack of more numerous sections other than transverse ones, I failed to discover the true contours of these organs. This, however, my two friends above named have done. The organ in question is evidently common to many of the *Lepidodendra*, though its significance has been overlooked by me until the two observers mentioned called my attention to it. At the same time I cannot accept the name they have given to the structure. They call it the *Ligule*. I cannot, however, recognise any homologous relationship between the membranous ligule of the living *Selaginellæ* and *Isoetes* and the peculiar organ of our fossil ones. Many features

* I may call attention, in passing, to a very characteristic stem of this type connected with the fine *Stigmaria* recently discovered at Osnaburg, and now in the Berlin Geological Museum. See "Der im Lichthof der Königl. geologischen Landesanstalt und Bergakademie aufgestellte Baumstumpf mit Wurzeln aus dem Carbon des Piesberges," von HERRN H. POTONIE, in Berlin, Plates 21 and 22 Separatabdruck aus dem 'Jahrbuch der Königl. Preuss. Geologischen Landesanstalt für 1889.'

about the latter suggest strongly that it may have been a glandular structure; hence I shall distinguish it by the name of the adenoid organ of the leaf.

Another organ is referred to by the same observers under the name of *parichnos*, assigned to it by M. BERTRAND. I had already worked out this organ, and prepared my figures and descriptions of it as they appear in the succeeding pages, when I received the Memoirs of MM. BERTRAND and HOVELACQUE, in which they speak of it. M. HOVELACQUE is inclined to regard it as a glandular structure. M. BERTRAND objects to this conclusion, and has adopted a name which he thinks sufficiently indicates his objection. Since I agree with M. BERTRAND on this point, I shall accept and employ his name of *parichnos*.

I have already observed that the arrangements of the small tracheæ at the periphery of the primary tracheal cylinder of my young twigs, illustrated by my fig. 6, Plate 3, are much less complicated than in the larger branches described by M. BERTRAND. This simpler condition is still more conspicuous in my yet younger, more recently-acquired section (C. N. 1596 G.), where the primary tracheal cylinder is closely invested by a zone of delicate, well-preserved parenchyma, ·01 in diameter. In this specimen the "points" of M. BERTRAND are less prominent even than in my other young branches, whilst the leaf-trace bundles are large and conspicuous. It is difficult to trace these bundles far down the exterior of the cylinder in longitudinal sections. They become inextricably intermingled with the numerous small tracheæ as well as with the cells, some spiral, others not, that often occupy the line of junction of the common bundles and the innermost cortex, or *couche libérienne* of my French friends. (See C. N. 3892). Where the leaf-trace first becomes fairly detached from the periphery of the primary tracheal cylinder, it consists solely of a number of very small tracheæ. Scarcely any portions of these are preserved, in the young specimens, in the vacant area between the neighbourhood of the cylinder and the inner border of the middle bark. But we not only find them at the innermost margin of the latter (as in figs. 9, 9A, and 10, at *c*, *c*), but they here present the double form characteristic of *L. Harcourtii*, having the inner and upper part composed of tracheæ, and a lower and outer portion consisting of an admixture of hard and soft bast—obviously the xylem and phloem of modern writers. A bundle in this condition is seen, intersected a little obliquely, in fig. 8, and another, cut across yet more obliquely, in fig. 11. In the former figure (C. N. 1596) we have the xylem on the left hand, *a*, and the phloem on the right hand at *b*. In fig. 11 we have the same arrangement at *a* and *b*. These arrangements are reversed in Plate 1, fig. 12, where *a* is the cluster of the tracheæ of the xylem, and *b* the hard bast of the phloem. In fig. 8 only the xylem and hard bast are preserved within the small circular area, *c*, from which all more delicate structures have disappeared. In fig. 11, which section is rather more oblique, we find, in addition to the leaf-trace, a number of very delicate cells, elongated longitudinally, some of which doubtless represent the soft bast. In some transverse sections we find the area *c'* of figs. 8 and 11 filled with similar delicate cells investing the entire

bundle. These cells suggest the idea of a concentric bundle, but on the whole I incline to the belief that they are really collateral.

In my larger branches, further points may be noted. In Plate 1, fig. 3, we find sections of a considerable number of leaf-traces, *c''*, scattered irregularly over the vacant area *c*. Each of these traces is surrounded by a zone of extremely delicate parenchyma, within which we find, in many cases, the phloem and xylem distinctly preserved in their normal positions. On reaching the middle cortex, *d*, these bundles, *c*, become extremely conspicuous, each of them occupying a circular or oval area, about ·1 inch diameter. On this large specimen we can readily trace the symmetrical diagonal curves, along which the sections of these leaf-traces are arranged; curves which correspond to the diagonal arrangements of the leaves at the exterior of the cortex. In each of these curves I usually find three leaf-traces, though, occasionally, a fourth can be detected at the periphery of the cortex. These diagonal curves start from the inner margin of the middle bark, and bend away in a segment of a circle towards the periphery of the cortex, the concavity of each curve pointing towards the centre of the branch. I find that the curves which bend outwards from left to right are twenty-four in number, whilst of those curving from right to left there appear but sixteen. On reaching the prosenchymatous zone of the cortex we find a new element associated with the leaf-trace. A tangential section of this zone of the cortex, intersecting one of these leaf-traces, is represented in fig. 13 (C. N. 380*k*), × 37. The imperfectly-preserved vascular bundle is seen at *c'*, whilst immediately above it we have, at *g*, a transverse section of the organ to which M. BERTRAND has given the name of "parichnos." No student of Carboniferous vegetation is ignorant of the fact that near the centre of each leaf-scale, left after the fall of the leaf of a *Lepidodendron* or *Sigillaria*, there are three small distinct marks. BRONGNIART believed all three to represent a similar number of leaf-traces. We have long known, however, that this was not the case. The central one alone is of that character, but what the other two were has long been unknown. The Memoir of M. BERTRAND throws some light upon them and gives them a name, but long before that Memoir was published I had obtained two magnificent series of sections of these objects illustrating their entire morphology. On making tangential sections like fig. 13, we find in *L. Harcourtii* a *rounded* cluster of cells enclosed in what resembles a more or less distinct sheath *resting upon* the upper surface of the vascular bundle. On a later page, similar, though modified, conditions in the corresponding parts of a Ulodendroid branch of a *Lepidophloios* will be described.

We may pause here for a moment to consider the external forms of the leaves of *L. Harcourtii*, as seen in transverse, radial, and tangential sections. Their outlines in transverse sections of the branches are seen in Plate 1, figs. 1 and 2; in longitudinal ones, Plate 2, figs. 9 and 9A; and in a tangential section, Plate 2, fig. 14. Further enlarged views, and more detailed organization, are represented in Plate 3. Of course, the forms of these leaves necessarily vary according to the planes, hori-

zontal or vertical, in which they are intersected, but all the variations show that these organs were extremely short and more or less quadrate in form, but having a somewhat prominent apex. Their fundamental tissue is parenchymatous, the cells becoming smaller, and with thicker walls, as they approach the epidermal surfaces, and in the immediate vicinity of the special organs seen in their interior. Fig. 14 shows their bases to be almost as quadrangular as those of a *Favularia;* but Plate 3, fig. 15, represents some of these leaves as they appear at part of the exterior of the specimen, Plate 5, fig. 7. I have ground these down in an unequal degree, dipping deepest into the specimen to the right of the figure where the sections are becoming more rhomboidal than in Plate 2, fig. 14. They are also much further apart than in the latter figure. On the left, I have chiefly brought their widely-separated tips into view. Here the small sections are almost triangular.

To master the details of their internal organization I have been compelled to obtain a very large number of sections of these leaves, since a complete knowledge of their structure could only be derived from the study of many such sections, made in a variety of planes. The chief special organs in their interiors consist of the leaf-trace, the parichnos, and the adenoid organs.

Plate 3, fig. 16, represents part of a leaf from the transverse section of a branch (C. N. 380*b*), × 27, in which the leaf-trace, *c'*, passes through the prosenchymatous zone, *e*, and terminates at *c''* in a fan-shaped arrangement of prosenchymatous cells, amongst which two or three barred ones can be detected.

Plate 3, fig. 17, represents a similar section to fig. 16, only the leaf is cut through at a slightly different horizon; hence at *g*, *g*, we now find the single parichnos, *g*, of fig. 13, divided into two, for the organ bifurcates soon after leaving the prosenchymatous zone of the cortex. Fig. 18 represents a similar section to the two last, showing sections of the two lobes of the parichnos, *g*, *g'*, but here the end of the leaf-trace, fig. 16, *c''*, has been intersected obliquely at *c''*; we now find that all the elongated cells which pass upwards in the direction of the apex of the leaf-trace are barred tracheæ, whilst those which pass downwards are ordinary prosenchymatous cells, an apparent division of the two constituents of the leaf-trace.

Plate 3, fig. 19, is one of the few vertical sections in which I have been able to observe the course of the leaf-trace from the middle cortex into the leaf. At *c* the trace distinctly displays the division into phloem and xylem. In the interior of the leaf this distinction cannot be observed. This trace seems to terminate below the apex of the leaf, and immediately above a point where the margin of the leaf is more deeply lobed than usual. Close to the apex of this leaf, *k*, we discover the organ to which I have given the name of adenoid, but which my French friends designate the ligule. We see it again at *h*, *h*, in a similar position, in the vertical sections through two leaves, figs. 20 and 21. We shall find this organ much more perfectly developed, though in a different position, when we examine the leaves of

Lomatophloios. The fact to be noted here is that the peripheral termination of this organ is at the prominent apex of each leaf.

I should next proceed to examine what I am convinced represents a series of Halonial states of *L. Harcourtii*, but before doing so it becomes necessary to submit to a careful enquiry what we must, in future, imply by the terms *Halonia* and *Ulodendron*, and especially whether we can any longer use these terms as generic names, or whether we must simply employ them as adjectives to indicate either a preparation for, or the actual attainment, of the condition of special fruit-bearing branches of any or all of the Lepidodendroid and Sigillarian plants.

I must first insist upon the recognition of some more definite characteristics distinguishing *Halonia* from *Ulodendron* than we yet possess. In Part II. of my Memoirs ('Phil. Trans.,' 1872), I introduced a long note on the close relations which then appeared to me to subsist between *Halonia* and *Ulodendron*. After 20 years of further study of the question, I find very little (and that little only applies to some minor points advanced hypothetically) that I am prepared to withdraw.

In his 'Tableau des Genres de Végétaux Fossiles' (1849), BRONGNIART, speaking of *Ulodendron*, says: "Ce genre ne me paraît fondé que sur un état particulier de certains *Lepidodendron*, dans lesquels il se développe sur les tiges volumineuses des tubercules coniques ou hémisphériques." He goes on to say: "Ces sortes de mamelons orbiculaires sont disposés en série longitudinale sur les deux côtés opposés de la tige à des intervalles assez rapprochés" (*loc. cit.*, p. 42).

On the next page he briefly describes the genus *Halonia*, respecting which he remarks that whilst Lepidodendroid in its general features, "la tige présente en outre de gros tubercules coniques *disposés en quinconce*, et sur lesquels s'étend uniformément l'écorce générale et les feuilles qu'elle supportait" (*loc. cit.*, p. 225).

Since these definitions were penned we have learnt much about *Halonia* and *Ulodendron*. In Memoir II. (*loc. cit.*, p. 225) I expressed my strong conviction that the tubercles, alike of *Ulodendron* and of *Halonia*, represent short abortive branches destined to support strobiloid forms of fructification. The accuracy of this conclusion was set at rest for ever when Professor D'ARCY THOMPSON discovered and described one of the forms of the so-called *Ulodendron minus*, with the strobilus *in situ*, attached to its Ulodendroid scar. That the *Haloniæ* were young terminal branches, and not roots, as many, including BRONGNIART himself, were inclined to believe, was in like manner set at rest, first by the final demonstration that the *Stigmariæ* were the true roots of the *Lepidodendra*, and, secondly, by my publication of the figure of the grand specimen in the museum of the Leeds Philosophical Society,* which settled, beyond all possibility of question, the fact that *Haloniæ* were the terminal divisions of Lepidodendroid branches. Starting from this foundation, I shall proceed to examine such facts as we are now acquainted with bearing upon this question.

* Memoir XII., Plate 34, 1883.

In the first place BRONGNIART's division of *Ulodendra* and *Halonieæ* into two groups, in the former of which the tubercles are in the centre of large flattened scars arranged in *two* vertical series on opposite sides of the stem, whilst in the latter we have *numerous* rows of similar tubercles arranged quincunctially, can no longer be accepted.

Plate 6, fig. 22, represents a small branch in my collection (C. N. 649 A) of its natural size, with the *tubercles* arranged as in *Ulodendron*, three on one side, *c*, *c*, *c*, whilst two on the opposite one occupy the centres of the two intervals *c*, *c*. The specimen is semi-decorticated, and in a condition identical with that of fig. 23 and the front portion of fig. 24. On comparing these three specimens it will at once be seen that the tips of their respective tubercles are in precisely the same condition. They all alike represent areas which reached the surface of the cortex, and through which *special* bundles of vessels passed into the slender axis of the strobilus which each tubercle once supported. Fig. 22 is obviously the youngest of these three branches, 24 being the next, and 23, which is reduced from the size of the original by one-third, has clearly grown enormously since it was a young terminal fructiferous branch. Figs. 23 and 24 obviously belong to the form known as *Halonia regularis*, and each of them has enlarged considerably beyond their normal diameter when they first began to develop as small lateral, arrested, fruit-bearing branches, of which the tubercles are the remaining indications. In the Owens College Museum, to which the specimens, figs. 23 and 24, belong, we have other much more slender branches of the same type, some of which are not more than ·5 in diameter.*

Before leaving the above three specimens, I would again call attention to the absolute identity in the form and aspects of their several tubercles as indicated by the letters *c*, *c*. In each case we have a small fractured circular area which once sustained some deciduous appendage. Had the prolongation beyond the broken circular area not been some deciduous organ, but merely abbreviated lateral branches, it would have been impossible for these tubercles to have retained such an absolute regularity of elevation, size, and form as they all present. It is obvious that each shoot was originally prolonged into something that is no longer preserved *in situ*. We are forced to the conclusion that the missing appendages must have been strobiloid reproductive organs. Turning to Plate 6, fig. 25A, we meet with further characters of interest. I am indebted for this important and beautiful specimen to my friend T. W. DAVIS, ESQ., F.G.S., of Chevinedge, near Halifax, who obtained it from a colliery in the neighbourhood of Wakefield. The specimen represents the exterior surface of the cortex, the leaf-cushions of which are beautifully preserved. Its striking feature consists in its three contiguous vertical columns of true Ulodendroid scars arranged in the so-called quincunctial manner characteristic of the

* The specimen fig. 18 is the one originally figured by Mr. BINNEY, and part of which was refigured from BINNEY's plate by M. RENAULT, where a mere crack in the matrix was represented as a rootlet, and quoted as proving that *Halonia* had been a root like *Stigmaria*.

tubercles of *Halonia regularis*. BRONGNIART describes this arrangement as quincunctial, but it is as easy to demonstrate that the circle of tubercles, of which each one is in turn a centre, consists of six, as of five. This is also the case with fig. 25A, in which the scars of each vertical series alternate, and are in close contact with each other within each circle. We have the usual broad Ulodendroid area which was merely compressed by, but not organically united with the deciduous appendage. The true point of organic union is very distinct in most of the circles, but especially so in those indicated by the letter *c*. On comparing these central points with the middle one, *c* of fig. 22, as well as with those similarly indicated in figs. 23 and 24, no doubt can be admitted to exist as to their being homologous. But this specimen suggests some further enquiries. On Plate 8, fig. 2, of his classic work on the 'Flora of the Primæval World,' STERNBERG represented a fragment of a Lepidodendroid bark, to which he gave the name of *Lepidophloios laricinum*. This figure is indefinite, in addition to being, in my conviction, turned upside down. Still, later, CORDA figured and described under the new name of *Lomatophloios*, a somewhat similar plant, and GÖPPERT a third, to which he gave the generic name of *Pachyphlæus*. Referring to these three plants, in 1849,* BRONGNIART says: "Ces trois genres me paraissent des espèces différentes d'un seul et même genre, auquel je laisse le nom donné en premier par M. DE STERNBERG," a determination with which I heartily agree, and could wish to see it adopted at the present day. Amongst other definitions of the genus *Lepidophloios*, BRONGNIART defines the cortex as "couverte d'écailles formées par les protubérances basilaires des feuilles, elles sont à peu près rhomboïdales, à grand diamètre transversal, terminées à leur angle *supérieur* par une cicatrice d'insertion des feuilles également rhomboïdale."

The above observations by STERNBERG and CORDA have led to a protracted controversy that has not yet come to an end. The opposing parties equally recognise the general form of the leaves of STERNBERG's *Lepidophloios* and CORDA's *Lomatophloios* as being identical, viz., that the transverse diameter of each rhomboidal leaf-base greatly exceeds its vertical one, and that its prolonged lateral angles are very acute, whilst its upper and lower ones are obtusely rounded; but the dispute that has arisen refers to the position of the leaf-scar, left by the fall of the deciduous leaf, upon what remains in the shape of a persistent pulvinus, or leaf-cushion. In his figure of *Lepidophloios laricinum* (Plate 2, fig. 2, of his work on the 'Flora of the Primæval World'), STERNBERG places this leaf-scar on the lower vertical angle of each leaf-cushion, the reverse of its usual position amongst the Lepidodendroid plants. At a later period, in his 'Flora der Vorwelt,' CORDA figured a plant under the name of *Lomatophloios crassicaule*, in the leaf-cushions of which he reverses this arrangement. BRONGNIART, as we have seen, unites the two genera in question with a third one, and assigns the superior position to the common group; later observers ranged themselves on opposite sides of this division; GOLDENBERG restored both

* 'Tableau des Genres de Végétaux Fossiles,' p. 43.

the genera *Lepidophloios* and *Lomatophloios*, assigning the upper position to the former one, and the lower to the latter, a course lately followed also by RENAULT. WEISS, in my mind, far more judiciously, reverted to BRONGNIART'S plan, and re-united the two genera.

But it is to be noted that most of the fragments of the plants concerned bear no characteristics enabling us to determine which is the upper and which the lower end of the specimen. This is the case with STERNBERG'S original figure; hence it would appear more reasonable that, in the absence of other features distinguishing *Lepidophloios* from *Lomatophloios*, the two should, in accordance with the views of BRONGNIART and WEISS, be united under the former name, as being that first published. But a small addition to the definition of the former, already quoted, should recognise the fact that in some examples of the genus the leaf-scar may occupy the inferior position. Anyhow, such will be the plan adopted in the following pages.

These Lepidophloioid leaves are well preserved in the fructigerous branch of which fig. 25A represents the natural size. Each circular area corresponds to what was primarily a very slightly projecting deciduous branch. In the centre of each circle is the flattened mamilla, *c*, of a Halonial tubercle. The Lepidophloioid leaf-cushions are arranged also in circles surrounding each Ulodendroid area. This arrangement is exactly what would occur where any young leafy shoot sprang laterally from a more vertical primary one.

In this specimen we thus find combined the tips of the tubercles and the multiplied vertical rows of a *Halonia* with the flattened orbicular areas of a *Ulodendron*. The question arises, what is the meaning of these combinations. I think the probable answer is easily found, but in seeking it we must first turn to the two fine specimens, figs. 26A and 27A.

Fig. 26A represents a specimen from the Lancashire coalfield, now in the Museum of the Owens College. The figure is reduced to two-thirds its actual size. We have here a Lepidodendroid stem, *a*, clothed with the long leaves of the Lepidophylloid type, so different from those of *L. Harcourtii* and its allied forms.

On its right we have a very short branch, *a'*, the development of which has been arrested by the growth of the fine *Lepidostrobus*, *b*, still united to it. If this cone could have been detached, we should, I doubt not, have found at its base, deep amongst the surrounding leaves, an area, the diameter of which would be the same as that of the base of the strobilus. The pressure of the latter would necessarily check the development of the underlying leaves. But in the centre of that compressed area would be a yet smaller circle representing the point of organic union between the abortive branch and the axis of the strobilus. This latter point would, after the fall of the strobilus, correspond in all its features with what we see in the centre of each of the scars, *c*, of fig. 25A. In fig. 27A we have a different arrangement. Here the strobilus, instead of being practically sessile upon an undeveloped *lateral* branch,

hangs from the extremity of a slender terminal twig, to the growth of which the presence of the reproductive organ has occasioned no apparent interruption.* I infer from the above and other similar examples that true Ulodendroid scars, whatever may be their number or arrangement, were produced by the pressure of strobili devoid of any conspicuous peduncles, and which, though really terminal upon arrested *lateral* branches, bore the aspect of being planted in a sessile manner, on the sides of ordinary ones.

In the *Haloniæ*, on the other hand, the peduncle of the strobilus, though short, projected sufficiently above the cortex to prevent the base of that strobilus from pressing so closely upon the sustaining branch as to depress or destroy any of its leaves. Of course, this result would be influenced by variations in the shape and size of the base of the strobilus. When this was fusiform and narrow, it would further facilitate the development of the Halonial type of tubercle. A conical strobilus, on the other hand, with a broadly obtuse base, would further tend to produce the Ulodendroid form. Such examples as fig. 27A carry us to the very extreme form of plants on the branches of which no traces of the detached organs of fructification remain.

It follows from the above observations that the only distinction between Halonial and Ulodendroid conditions lies, not in the number or arrangement of the fruit-scars, but in the presence or absence of a pressure disk surrounding each true fruit-scar. The flattened examples so common amongst the Carboniferous shales are in a most abnormal condition. The larger ones represent old arborescent stems from the interiors of which every trace of organic matter has disappeared; nothing remains of the original branch save a very thin film of coal, on the surface of which is impressed many of the details of leaf-scars, &c., with minute exactness; but such stems, reduced by decay to the state of thin-walled unresisting cylinders, thrown down and overlaid by masses of mud and sand, soon had all the undulations of their exteriors reduced to a more or less uniform plane.

The normal contours of such arborescent Ulodendroid forms, not altered by vertical pressure, are seen in a noble specimen in the Museum of Owens College. This stem is 7 feet 6 inches in height, and has a circumference of 3 feet at 1 foot from its upper end, of 45 inches at a lower point, and of 48 inches near its base. It has eight scars on each side, at intervals of about 11 inches between the centres of the scars; each centre being at the bottom of a deep depression, apparently produced by the outgrowth of the thick surrounding cortex, such as we find in any old tree wherever the removal of a branch in its youth has left an area uncovered by that cortex. This fine specimen was obtained from the Colliery of Messrs. Miles, Settle, and Co., at D'Arcey Lever, and presented by them to the College Museum. It is an example of the kind of specimen that must be studied if a true conception of these Ulodendroid

* I have lately received from Sir William Dawson a photograph of a fine example resembling fig. 27A, which he proposes to call *Lepidodendron Cliftonense*.

forms is to be arrived at. For the specimen, fig. 27A, which I presented to the Owen's College Museum, I was indebted to CHARLES B. CRAWSHAW, Esq., of the firm of CRAWSHAW and WARBURTON, in whose "Saville" pit at Soothill, near Dewsbury, the specimen was found in a layer immediately above the Joan Coal.

The way is now cleared for reverting to the internal structure of some of these Halonial and Ulodendroid forms, of which I fortunately possess very fine examples. In the long note in my Memoir, Part II., to which I have already called attention, I described the way in which small but complete segments of the entire primary tracheal cylinder were sometimes detached to form the vascular bundles supplying the fruiting branches, the result of which segmentation was that at the point whence this diverted segment had been removed, a gap was left in the vascular cylinder analogous to the "foliar gap" seen in ferns under somewhat similar conditions, and described by DE BARY. GRAF ZU SOLMS on p. 231 of his 'Fossil Botany,' English translation, refers to the section described in my Memoir II. He says, "I have seen the preparations in WILLIAMSON'S collections, but they have unfortunately never been figured." I now remedy this omission.

Plate 2, fig. 25, is a vertical section, enlarged five diameters, of part of a Halonial or Ulodendroid branch of *Lepidodendron fuliginosum*, which bore some distinct tubercles. We have the medulla of the main branch at *a*, enclosed within the primary tracheal cylinder at *b*. At *c* an ordinary leaf-trace is being given off from the exterior of the cylinder. But at *l* an *entire segment* of the cylinder is detached, and proceeds outwards in the same direction as the leaf-trace *c*; and through the gap thus produced in the cylinder, the medulla *a* and the innermost cortex *d* are brought into contact, the cells of the former being readily distinguishable by their size, being larger and their shapes more irregular than those of the cortex. The divergent bundle, *ll'*, consists apparently of a solid cluster of barred tracheæ without any trace of a central medulla. It is accompanied in its outward course, especially on its underside *m*, by numerous parallel lines of small cortical cells; these may possibly represent phloem elements. The radial arrangement of this tissue constitutes a very conspicuous feature of transverse sections of *L. fuliginosum*. I presume that this is the tissue to which M. BERTRAND gives the name of Liber. The above may be accepted as an example of one of ordinary methods in which these fruiting branches obtain their supplies of vascular tissue. I have previously described a slightly different way in which these fruiting branches obtain similar vascular supplies. Thus in my Memoir, Part XII., on Plate 32, figs. 21, 22, 24, and 25, and on Plate 33, fig. 23, I have represented various conditions of the Halonial branch of the Arran *L. Wunschianum*. There is no medulla in the central xylem strand in any of the *young* twigs or branches of this species. The xylem strand consists of a solid mass of tracheæ. A cluster of these tracheæ is pinched off from the exterior only of the strand which becomes moulded, on its way outwards through the cortex, into a solid cylinder like that of fig. 25 *l*.

Having thus endeavoured to sketch the general features of the fruiting branches of these Lepidodendroid plants, I must now return to *L. Harcourtii.*

In Plate 1, fig. 1, I have represented at *b'* a small segment of the primary tracheal ring, which is being detached and is carrying along with it, at its inner surface, some of the medullary cells. We have here a parallel example to what I have represented in Plate 5, figs. 1 to 6, of my Memoir, Part XVI., where a similar arc of a vascular cylinder, fig. 3, carries along with and on one side of it, a cluster of medullary cells. In fig. 3 we find this arc converted into a solid terete bundle from which all recognizable cells have disappeared. This example bears, in an important manner, upon some questions about to be considered. Had such a succession of different conditions merely been detected in an unconnected manner in several distinct but homologous bundles, even in the same plant, though the facts might have given us strong grounds for concluding that one and the same bundle could undergo similar alterations of structure in the several parts of its continuous course, we should have had no absolute proof that such changes did take place. But in the example quoted above we have positive demonstration that such changes are not only possible, but that they do actually occur. The several sections referred to above, were prepared with the utmost care and exactitude, and represent the changes undergone by the same identical bundle between its first separation from the primary tracheal cylinder to its arrival at the outermost zone of the cortex. We may therefore expect to find that a segment like fig. 1*b'* of this Memoir may undergo similar changes, and our expectation will not be disappointed.

Plate 1, fig. 26, represents a transverse section of a branch of *L. Harcourtii*, which is in the Halonial state, but in which the lateral abortive branches seem to have been more or less biserial. The primary stem *A* scarcely differs from fig. 1, the medulla *a* and its primary tracheal cylinder *b* being substantially identical in the two cases, which remark is equally applicable to the cortex and the leaves. But, in addition, we have the two lateral branches *B* and *C* springing from opposite sides of *A*, and from the difference in their degrees of growth they seem to have been given off in alternating order. Their cortical zones and foliage differ in no respect from their continuations round the central stem, but this cannot be affirmed of the central bundles *l'l* and *m'm* of the branches. In each of these the central xylem strand consists of a single cluster of tracheæ, no separation into medulla and primary tracheal cylinder having taken place; fig. 28, *a*. (I have in my cabinet a second section (C. N. 380*a*), also × 4, but which has intersected the tubercular branch *B* nearer to its apex, as is indicated by its smaller diameter. This section of *B* is represented in fig. 27). As already mentioned each of these arrested branches was clothed with the ordinary leaves of the species up to its apex. Fig. 29 is a vertical section through another of these Halonial twigs, in which *A* is the primary axis, and *B* the arrested Halonial tubercle. At *a* we have the primary xylem strand, differentiated into medulla and primary tracheal cylinder; whilst at *b* we have, separating from *A*, a

large strand resembling that already represented at *l*, in Plate 2, fig. 25. This strand is further enlarged in Plate 4, fig. 29*. On examining the transverse section of a similar strand, as represented in the enlarged fig. 28, we discover that it consists of a central mass of tracheæ, *a*, within which no traces of medullary cells can be detected. This strand of tracheæ is immediately invested by an imperfectly preserved and undefined zone of minute cells, *b*, in which we find a number of very clearly defined leaf traces, *c*. Similar leaf traces, *c'*, are also scattered through the yet more external cortex, *m*, which obviously represents the zone that has disappeared from the sections (figs. 1, 3, 26A, 29).

The specimens just described demonstrate that, like so many of the *Lepidodendra*, the *L. Harcourtii* developed Halonial fruit-bearing tubercles at the extremities of its youngest branches, from which we may infer that its strobili must have been lateral, and more or less sessile appendages to those branches. BINNEY and HOOKER have alike described *Lepidostrobi* which they associate with *L. Harcourtii*, but I see no reason for accepting this identification.

We must next examine a most instructive specimen from Hough Hill Colliery, Stalybridge, collected by my old friend and auxiliary, Mr. GEORGE WILD, of Bardsley, near Ashton-under-Lyne, who, true to his old character, has handed over one more of his valued specimens to Mr. LOMAX and myself, allowing us to cut it in pieces in any way calculated to advance our palæobotanical researches. The specimen was one in which the large Halonial protuberances had been in two lateral series, three of these protuberances being preserved. Its leaves show that it has belonged to the Lepidophloioid group, and present every appearance of identity with the plant which is described and figured in my Memoir, Part II. ('Phil. Trans.,' 1872, pp. 209, 210, figs. 24–28), but our new specimen, being in an extremely beautiful state of preservation, teaches us much of which we were previously ignorant.

The diameter of the stem within the defined prosenchymatous zone, when uncompressed, has been about 2·5. The central xylem strand (Plate 4, fig. 30), consisting of medulla, *a*, and primary tracheal cylinder, *b*, is preserved, and corresponds in its details of structure with the ordinary Lepidodendroid forms. It gives off, from the concave crenulations of its peripheral margin, the usual leaf traces, with here and there a vascular bundle of much larger dimensions, of which the tracheæ, as seen in the transverse section, sometimes arrange themselves in an approach to a radial order (see C. N. 1952 and 1955). The inner cortex is ill preserved, but much of the middle cortex, *d*, remains, extending uninterruptedly to the prosenchymatous zone, *e*, which latter has a thickness of about ·1.† A thin external cortex, *f*, of about the same thickness as the prosenchymatous zone intervenes between it and the bases of the leaves.

† This prosenchymatous zone evidently developed in the way illustrated in my Memoir on *Stigmaria ficoides* (Palæontographical Society's volume for 1886, Plate 8, figs. 22, 23). The meristemic zone in this *Lepidophloios* is shown in all the sections like fig. 30A, where we have the normal prosenchyma at *a*; at *c* is the outer cortex; and between the two, at *b*, the meristemic zone.

The foliage is of the true Lepidophloioid type, but the forms of the leaves vary according to the planes and directions in which sections of them are prepared. Their appearances in transverse sections of the stem are seen in figs. 30, 31, and 32, and vertical sections are shown in figs. 33 and 34. The two latter exhibit the general falcate form and arrangement which I illustrated in my Memoir II., Plate 28, fig. 27. Unfortunately, the extreme tips of the leaves now figured have been disorganized and have disappeared. Nevertheless, what remains of them is of the utmost value, illustrating, with extreme clearness, the detailed structures of this type of the Lepidodendroid foliages.

Fig. 30 illustrates the extreme differences in the forms of these leaves, as seen in transverse sections of the stem. Their almost uniform contour, as shown by sections made tangentially to the periphery of the branch is represented by Plate 3, fig. 35 (C. N. 1972–3, and 4). Turning first to fig. 35, representing one of the latter sections, we find the leaf-trace cut across at *c*, as also are the two lobes of the parichnos at *g*, *g*. The adenoid organ is cut across at *h*. In fig. 31 we have the leaf *g'* of fig. 30 enlarged seven diameters. At *c* the leaf-trace is ascending towards the apex of the leaf; on each side of its apical extremity we have, at *g*, *g*, portions of the two lobes of the parichnos; whilst at *g'* we observe the inner extremity of the leaf-trace passing through the prosenchymatous zone *e* of the cortex. (C. N. 1955.)

Fig. 32 represents a similar section (C. N. 1956) to fig. 31, but passing through a plane rather nearer the upper surface of the leaf; hence, whilst we find the upturned extremity of the leaf-trace at *c*, we have the two lobes of the parichnos at *g*, *g*, but which lobes coalesce, as they pass inward at *g'* into the prosenchymatous zone, *e*. These conditions are further illustrated by fig. 35, which represents the lower parts of these structures at the inner part of a section (C. N. 1946) like fig. 32, but further enlarged to 13 diameters. We here find the foliar bundle at *c*; the two lobes of the parichnos at *g*, *g*, but these two lobes coalesce into one at *g'*, where, as will be demonstrated shortly, these united lobes enter the prosenchymatous zone, *e*, resting upon the corresponding portion of the leaf-trace.

The two figures, 33 and 34, represent vertical sections through two of the leaves of our plant, in each of which *a* represents the injured apical extremity of the leaf, and *b* its base, broken off close to the prosenchymatous zone. These sections demonstrate that the central part of each leaf consists of a large form of parenchyma, which approaches nearer to the lower than to the upper surface of the leaf. On approaching the upper surface especially this parenchyma passes rapidly into a thick zone of small and quickly-narrowing prosenchymatous cells, forming a protective layer. In fig. 33 we find the leaf-trace at *c* curving outwards in a line closely parallel with the upper surface of the leaf, and exhibiting a small fragment of one of the lobes of the parichnos at *g*. Fig. 34 represents a similar section to 32; only, the section having passed a little on one side of the leaf-trace, it has, at *g*, cut through nearly the entire length

of one of the lobes of the parichnos at *g*, which also is in close contact with the prosenchymatous upper surface of the leaf, and follows its curvatures.

The two sections, figs. 36 and 37, throw additional light upon the structures just described. Fig. 36 represents a transverse section of a leaf-trace when passing through a tangential section of the cortex, nearly in contact with the prosenchymatous zone, as in fig. 35, *g'* (C. N. 1971). The cells filling the interior of these figures of the parichnoid organs accurately represent the character of this tissue, though unfortunately they throw no light upon the functions which these organs performed when living.

Fig. 36, Plate 4, represents a section crossing the leaf-trace *c* transversely, surmounted by the corresponding section of the parichnos, *g'*, where the two pass together through the cortex immediately externally to the prosenchymatous zone, as at fig. 35, *g'* (C. N. 1971, × 50). We now find the two lobes of the parichnos united into a concavo-convex organ, in the concavity of which the leaf-trace, *c*, is in close contact with it. This is the form assumed by all these leaf-traces as they pass through the outermost cortex to enter the base of the leaf. Fig. 37 represents a section made parallel to the last, but intersecting the leaf as nearly as possible in the plane of the leaf-scar left on the leaf-cushion after the fall of the deciduous leaf (C. N. 1973, × 40). We now find the leaf-trace, *c*, and the sections of the two lobes of the parichnos, *g*, *g*, in the exact relative positions occupied by the three points mistaken by BRONGNIART for three distinct leaf-traces, and which, so far as the points *g*, *g* are concerned, have been so long without having much light thrown upon their morphology and histology. This obscurity, however, exists no longer. M. RENAULT some time ago expressed an opinion that a difference in the form of the sections of these organs constituted a generic distinction between *Sigillaria* and *Lepidodendron*. I long since rejected this conclusion, and we now have proof that the form is a variable element. The same author regarded them as gum-canals, and was of opinion that they passed through the entire cortex—an opinion which Count SOLMS is unable to accept on such evidence as M. RENAULT had then furnished ('Fossil Botany,' English translation, p. 258). My specimens, now described, certainly support the Count SOLMS' conclusions on each of these points. So far from the parichnoid organs supplying any evidence of generic, much less of class, differences between *Sigillaria* and *Lepidodendron*, the fact that the two genera alike possess these very remarkable and unique structures affords a strong additional proof of their close relationship.

In fig. 37 we find that the vertical section has passed through the curious adenoid organ at *h*. Had the section been made nearer to the base of the leaf, this would not have been the case. Both the central mass and the walls of the cavity in which that mass is lodged present the charred aspect so characteristic of this structure. We find this organ commencing near the centre of the leaf at *h* of the vertical section (fig. 33), at which point of origin its diameter is the greatest. As it proceeds out-

wards, in the direction of the apex of the leaf, it bends downwards towards a point near to, but somewhat below that apex.

Fig. 38 represents a portion of a vertical longitudinal section of a leaf (C. N. 1957, ×125), like fig. 33. The uppermost part of the true leaf-trace, *c*, is composed of long and generally very narrow tubular fibres, below which is a line consisting of a few elongated barred tracheæ, *c'*, which constitute the true vascular elements of the leaf-trace. I discover no distinct evidence of a phloem connected with this leaf-trace; but as it is surrounded by more or less prosenchymatous cells, *b*, *b*, a phloem may be imbedded amongst them. In this latter portion, *b*, where many of the cells, though pointed at their two extremities, become almost parenchymatous, a few of them are converted into spiral tracheæ, as at *c''*, *c''*.

There yet remain to be considered some other examples of the vascular bundles going to the Halonial and Ulodendroid fructigerous tubercles. I have already described that of *L. Harcourtii* (Plate 1, fig. 28), so far as a transverse section of it is concerned. In Plate 3, fig. 29, a longitudinal section of a corresponding bundle is seen at *b*, supplying the Halonial tubercle B.

Plate 4, fig. 29*, represents a portion of the same bundle, enlarged 40 diameters. Like the transverse section, it exhibits, at *c*, a solid strand of barred tracheæ, with no indications of intermingled cells, whilst at *c'*, *c'* we have traces of an investing cylinder, composed of elongated cells; but I cannot positively identify these with a phloem zone, though such may be its nature.

Fig. 39 represents a tangential section through a part of the branch Plate 4, fig. 30, intersecting transversely one of the fruit-bearing tubercles in a plane near its base. We here have a very large number of tracheæ, showing a slight tendency to arrange themselves in a radial order, and with vague traces of some cellular tissue intermingled with these tracheæ (C. N. 1976, ×33). I have retained in my cabinet one of these tubercles in its integrity. At its conical apex, this tubercle exhibits exactly the same contour as those to which I have already called attention in figs. 22, 23, and 24*c*, but, in addition, the vessels constituting the large bundle corresponding to Plate 4, fig. 39, are conspicuous at its apical extremity, each trachea being filled with white earthy matter. This fact demonstrates the absolute certainty that the tubercle was once prolonged into some large deciduous appendage that has now disappeared, and which can only have been a strobilus, a large deciduous organ of any other kind being a wholly unknown thing amongst these Lepidodendroid plants.

In Plate 7, fig. 40, we have a portion of a transverse section of a tubercle belonging to a larger Ulododendroid stem than those already described. The transversely intersected divergent bundle, *l*, is again wholly tracheal, consisting of a very large number of vessels, and having a diameter of about ·07. This is immediately invested by a cortical zone of very minute cells, *k*, which, in turn, is surrounded by another zone, *m*, of similar cells of rather more variable sizes. This, again, is invested by an imperfectly completed circle of radially arranged prosenchymatous cells. Still more externally we

have the ordinary cortex of the parent branch. The prosenchymatous zone encloses a circle about ·2 in diameter and is considerably external to the structures represented in the figure, which is enlarged 10 diameters. The parts contained within the prosenchymatous boundary, which latter has followed the slopes of the contracting conical tubercle, also incline inwards as they ascend towards the apex of that organ.

I must call attention to yet one more section of one of these tubercular vascular bundles (C. N. 645 B). Fig. 40A represents a longitudinal section through the bundle of another Ulodendroid tubercle, for which I am again indebted to my invaluable coadjutor, Mr. WILD. It is enlarged 18 diameters. Its tracheal bundle, *b*, consists of the ordinary type of barred vessels, but in its centre, *a*, we find three or four distinct columns of parenchymatous cells, of the same type as those common in the interior of Ferns, DE BARY'S medullary cells. The periphery *d* consists of cortical cells. This development of medullary cells in the interior of a large Halonial or Ulodendroid bundle is a notable fact, which we shall shortly find to have some special significance. That the bundle is a true tubercular one is beyond question.

There still remain for consideration some additional observations respecting true Lepidodendroid strobili. BRONGNIART pointed out the necessity for the temporary retention of the name *Lepidostrobus*, only because, in his time, no clue whatever had been obtained for the identification of any one of these objects with any individual species of *Lepidodendron*, and no subsequent attempt of importance has been made to classify them. Many of the small fragments enclosed in nodules of clay ironstone, so often found at various localities, are not *Lepidostrobi*. Too frequently they are merely terminal portions of ordinary Lepidodendroid branches; besides these, true *Lepidostrobi* are not rare in such nodules, but the majority even of these are nothing more than casts, from which all structure has disappeared.

In some of my previous Memoirs I have recorded such fragmentary specimens as fell into my hands. We are now in a position to advance a little further, both in reference to their internal organization and in the identification of some of them with the parent *Lepidodendra* to which they belonged, in addition to the preceding remarks respecting the mode of their attachment to the branches of their parent trees.

In my Memoir, Part IX., and again in Part X., I figured and described a new form of fructification, remarkable alike for the structure of the strobilus and the grouping of its spores.* In Part XVI. I also described a young *Lepidodendron*, which appeared to be sufficiently distinct from all other known types to merit the provisional name of *L. Spenceri*.† Since the last of the above Memoirs was published I have obtained specimens highly suggestive of the probability that the strobilus of Memoir IX. and the twigs named *L. Spenceri* belonged to the same plant. This probability is now converted into a certainty by a specimen received from Mr. LOMAX,

* Part IX., Plate 22, figs. 38 to 57; Part X., Plate 15, figs. 11 and 12.

† *Loc. cit.*, figs. 19 to 22.

and now represented by fig. 41, Plate 7. It is an obliquely transverse section through a branch of *L. Spenceri* (C. N. 624*e*, × 10), but at its upper extremity, A, it bears a portion of the strobilus of Memoir IX. This part of the section is further enlarged to 17 diameters in fig. 42. *a* and *a'* are two of the characteristic sporangiophores of the strobilus, each having its small vascular bundle at the points indicated by the above letters. At *b* there is part of a sporangium, retaining some of its sporangial wall at *c*, *c*, and within it we have several very fine examples of spores, each with its peculiar investment of sterile cells described in Memoir IX. Two of these spores are represented in Plate 7, figs. 43 and 44. In 43 we have the central spherical cell of the group at *a*, containing its solitary spore, *a'*, enlarged 200 diameters. This is surrounded by a ring consisting of apparently three sterile sister-cells, *b b b*, but their exact number is not easily ascertained. These latter are distinctly hollow and inflated, but contracted to a thin margin internally where in contact with the mother-cell of the spore, and yet more so peripherally, where each one is flattened and thin.

In fig. 44 we have a second group like fig. 43, but here the spore is cut across, revealing at *a* an internal triangular cavity, around which is the substance of the spore, *a'*, consisting of a mass marked by a series of parallel lines. The divisions of the sterile cells, *b*, *b*, are even less distinctly defined than in fig. 43.

In Plate 8, fig. 45, we have a portion of one of these cell-clusters, enlarged 280 diameters, where *a*, *a* represents the central cell of the spore, and *b* is the zone along which one of the narrowed sister-cells was united to the central cell. These conditions are further illustrated in Plate 9. In Plate 9, fig. 46, we have one of the sister-cells detached from the central cell of the spore, but showing again, at *b*, its narrowed line of attachment to the fertile cell. At *b' b'* is its dilated portion, and at *b'' b''* its thin outer carinal margin. Figs. 47 and 48 represent the common aspects of these spores under low powers, with the reference letters as in the other figures. Fig. 49 is a single spore, having on its surface a triangular line, which may bear some relation to the triangular centre of fig. 44.

Fig. 50 represents the most perfect vertical section through the centre of a strobilus of *L. Spenceri* that I have yet seen (C. N. 624), enlarged $9\frac{1}{2}$ diameters. At *b* we have the barred vessels of the primary tracheal cylinder. At *c*, *c* are bands of the more internal cortex.* At *d*, *d* is its middle and outer cortex. The sporangiophores, *e*, are dilated at their peripheral ends, and each of the sporangia, *f*, is bounded by a wall, *f'*, consisting of a single layer of cells. It is difficult to determine with absolute certainty the point of attachment of the sporangia to the sporangiophores, but I believe that the sporangium rests upon the upper surface of its sporangiophore, and that the organic connection of the two is seen at *e'*, *e'*, at two of the upper sporangia, to the right of the figure. At both these points there is an indentation near the upper margin of the expanded sporangiophore, and opposite the same point we not unfrequently see a hook-like termination, *f''*, of the section of the sporangial wall,

* See the transverse section of this strobilus in Memoir X., Plate 15, fig. 12, *d*.

indicative of some interruption of its continuity, such as union to its sporangiophore would occasion. The vascular bundles supplying each of these sporangiophores pass outwards through the cortex, much in the same way as do ordinary leaf-traces; but I have not been able to detect them at the ends of these organs, where their position would demonstrate the point of union between the sporangium and its sporangiophore. I have already shown (Part XVI.) that the vegetative organs of *Lepidodendron Spenceri* present some strongly distinctive features: the present determination of its Lepidostroboid fructification brings out still more prominently the marked individuality of this rare type, and seems to justify its recognition as a distinct species.

In my Memoir, Part III., I described both the vegetative and reproductive organs of the plant from Burntisland to which I gave the name of *Lepidodendron brevifolium*. All subsequent experience of these beds, at Petticur, confirm my conviction that we have only found in them one species of *Lepidodendron*, and that the very youngest twigs and the matured branches, with all their specialized intermediate conditions, merely represent various stages of the growth of the same plant. If, as I believe, this is the case, we cannot hesitate to identify with it the numerous macrospores and the heterosporous *Lepidostrobi* that I found associated with the vegetative organs, and which I described in the same Memoir. In Plate 44, fig. 28, I represented four sporangia containing unmistakable macrospores, which I found at the base of a *Lepidostrobus*, the remaining sporangia of which were filled with microspores. Though so fragmentary as regards size, the specimen sufficed to establish the fact that the *Lepidodendron brevifolium* was a heterosporous form. At a later period Mr. CARRUTHERS was fortunate enough to obtain a section from the same locality, containing two superb *Lepidostrobi*: these he has kindly allowed me to figure. Each of the two figures, 51 and 52, on Plate 8 is enlarged $4\frac{2}{3}$ diameters. It is not necessary to dwell upon the details of the structure of these *Lepidostrobi*, since they were so fully described in my Memoir, Part III. These new examples have attained to a somewhat larger size than my older ones did; but they more especially illustrate the magnitude to which the lower, or macrosporal, portion B attained, as well as the sharp boundary which, alike in 51 and 52, separates this from the upper or microsporal half A.

I have for many years endeavoured to discover some specific character by which different *Lepidostrobi* could be distinguished and identified, but thus far my efforts have been unsuccessful. At one time I thought I had obtained such specific features in the forms of the transverse sections of the sporangiophores; but I eventually found that whilst differences exist between such sections, intermediate forms occurred so frequently as to make definitions based upon them difficult, if not impossible. I have, however, figured in Plates 8 and 9 some of the more distinctive modifications that I have observed. Figs. 53 and 54 represent one of the most striking and longest known of these forms. The specimens were collected by Professor PRESTWICH, at Coalbrook

Dale, more than half a century ago, and were noticed in his classic Memoir on the geology of that Coalfield.*

Some of the principal vegetable forms collected by Mr. PRESTWICH were described and figured by the late Professor J. MORRIS, amongst which was the specimen Plate 8, fig. 54, to which he gave the name of *Lycopodites (?) longibracteatus*. This specimen demonstrates that the fructification was terminal at the end of a slender branch. A second of the same species, fig. 53, is a still finer one. The sporangia are conspicuous at *a*; but the most prominent feature of this type appears in the large size and leafy aspect of the terminal portions of the sporangiophores *b*. The originals of these two specimens are in the British Museum, under the care of Mr. CARRUTHERS, who kindly permitted me to figure them. They are drawn of the natural size. Fig. 55 is a vertical section of the apex of a small specimen, also in the British Museum, with leafy termination to the sporangiophores, though less conspicuously so than in figs. 53 and 54. Fig. 56 is a transverse section, enlarged six diameters, of a fine fragment of a strobilus in the same collection, but obtained from Oldham. In it we have, at *b*, well defined sections of the overlapping free ends of the sporangiophores, which have somewhat the form of similar sections of leaves of *Lepidophloios*. The sections of ROBERT BROWN'S classical "Triplosporites" ('Linnean Soc. Trans.,' London, vol. 20, Part 3, T. 23, figs. B, C, D), show the radial and lateral dimensions of similar sporangiophores to be nearly equal; hence, in this example these organs were much less foliaceous than in fig. 56.

Fig. 57 is a fine longitudinal section of a *Lepidostrobus* (× 4, C. N. 1614), with radially elongated sporangia and sporangiophores. It is homosporous.

Fig. 58 is a transverse section of a fine homosporous *Lepidostrobus* from Oldham, enlarged $3\frac{1}{2}$ times (C. N. 568). In its centre we have a *facsimile* of the structures seen in the same position in the vegetative twigs of most of the young *Lepidodendra*. This portion of the section is further enlarged to 15 diameters in Plate 1, fig. 59, where we have special features of some importance. At *a* we have the space originally occupied by a medulla; at *b* is the primary tracheal cylinder, surrounded at *c* by numerous vascular bundles identical with the leaf-traces of the ordinary section of a young Lepidodendroid branch, but here destined to be distributed to the sporangiophores. One of these bundles is further enlarged in Plate 8, fig. 60. At *c*, in this figure, we have the tracheal, or xylem, elements of the bundle, and at *c'* is invariably a vacant space, which was, beyond doubt, originally occupied by the phloem portion of the bundle, which was obviously a collateral one. Where the xylem, *c*, of each bundle is still in close contact with the cylinder, *b*, as in fig. 59, this vacant space does not exist; neither are these tracheal strands as yet invested by the ring of conspicuous cells which the more external ones receive from the innermost zone of the cortex. The close resemblances of these bundles going to the sporangiophores, both in structure and origin, to the corresponding ones supplied to the leaves of

* 'Geol. Trans.,' 2nd series, vol. 5, 1840.

ordinary Lepidodendroid branches, suggests that these sporangiophores are modified leaves. If so the term "Sporophylles" is an appropriate name to be assigned to them.

Plate 6, fig. 61, represents a portion of the same *Lepidostrobus* as fig. 58, but whilst at the left-hand portion of the figure the sporangia *a* and the sporangiophores *b* are intersected tangentially, on the right hand the same organs *a'* and *b'* are cut through more radially.

Plate 6, fig. 62, represents a restoration of a radial section of this strobilus, in which we have the medulla of the central xylem strand *a*, at *a'*. At *a''*, *a''* is the primary tracheal cylinder; *b*, the sporangiophores; *b'*, expanded peltate extremity of the sporangiophore; *b''*, *b''*, the leaf-traces supplying the sporangiophores; *c'*, the wall of the sporangium; and *c*, homosporous spores. In his memoir on *Lepidostrobus*,* Mr. BINNEY described and figured the above species twice over. Once (*loc. cit.*, Plate 7) from the specimen from which my sections were also derived, when he assigned to it the name of *Lepidodendron Harcourtii*; and again, in Plate 8, when he gave to it the name of *L. vasculare*. I am obliged to reject both these specific determinations. Indeed, Mr. BINNEY himself adopted the latter name, "not without doubt." As to the example figured in his Plate 57, he says that its structure "is so closely identical with that of the stem of *Lepidodendron Harcourtii* that there can be little doubt as to its having been the fructification of that plant" (*loc. cit.*, p. 48). After his death I had the opportunity of studying, very carefully, Mr. BINNEY's entire collection of sections, and can affirm that it did not contain the smallest fragment of *L. Harcourtii*.

In his Plate 7, fig. 8, Mr. BINNEY has given a restoration of a sporangium and contiguous sporangiophore of this strobilus, but he has unfortunately suspended the former organ *under* the latter one, instead of reversing these positions.

I continue to shrink from giving specific names to examples which, in all probability, only represent types of forms reappearing in more than one species; but, as in a prevous Memoir, I still recognise the opposite inconvenience of having no concise means of referring to any object figured. With a distinct understanding as to the meaning and purpose of such names, and since the *Lepidostrobus* under consideration is rather characteristic of the Oldham deposits, I will designate the type *L. Oldhamium*.

In my Memoir, Part IX., I first called attention to the profusion of macrospores of a characteristic type, contained in the nodules obtained from the Halifax coals (*loc. cit.*, Plate 23, figs. 58–60), and in Part X. I figured and described (*loc. cit.*, Plate 15, fig. 8) a small crushed strobilus, in which these macrospores were also associated with a small fragment of a sporangium containing some microspores. This combination is better illustrated by the fragment from Halifax, represented in Plate 9, fig. 63. Here we have three distinct macrosporangia *a*, *b*, *c*, and three microsporangia *d*, *e*, *f*. In the sporangium *a* we have two macrospores with their characteristic fringes of

* Palæontographical Society's volume for 1870.

hair-like appendages. In *b* there are three of these objects, and in *c* but one. The other three sporangia are crowded with microspores. I have also received from Mr. KIDSTON an abundant supply of what I have no doubt are similar macrospores, from Scotland.

Knowing so little about the true form and structure of this strobilus, I do not venture to give it even a provisional name until more perfect specimens are discovered.

Plate 9, fig. 64, is an oblique vertical section through an unknown *Lepidostrobus* from Oldham, which illustrates the considerable variation observable in the sizes and forms of sections of the sporangiophores, according to their positions and the directions in which they are intersected. This seems to me to be a young fructification in which the sporangia either are not developed, or else their dimensions must have been so small, that the section has not passed through any of them.

Lepidostrobi have been found in the beds at Laggan Bay, in the Island of Arran. I have both longitudinal and transverse sections of one in the Museum of the University of Glasgow, for which I am indebted to JOHN YOUNG, Esq., the able Curator of that Museum, but they unfortunately contain no spores, and their structure is so imperfectly preserved, that no specific features can be detected in them.

Mr. BINNEY (*loc. cit.*, Plate XI.) has figured fragments of three *Lepidostrobi* from the volcanic ash of Laggan Bay, each of which is heterosporous. They are smaller than my specimen, but this may merely be a question of age, since in them the spores are preserved, whereas in mine they have all been shed. Since I have thus far obtained no evidence that we have in these volcanic deposits more than one type of *Lepidodendron* (*L. Wunschianum*), there are strong reasons for believing that it was a heterosporous form.

We have at least arrived at one result from the investigations recorded in the preceding pages; we now know that *L. Harcourtii* was not a distinct form teaching an independent and special philosophy. So far as its history is now known, it is substantially identical with that of the other known *Lepidodendra*, teaching the same truths and leading to the same inferences. We only want, in my opinion, to discover it in its arborescent condition, to place it side by side with *L. Wunschianum*, as a true typical exogenous Lycopod, and with which it has several extremely close relationships.

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* Number which the specimen figured bears in the author's cabinet.

Plate.	Fig.		Page of the memoir where described.
2	5	A segment of a transverse section of a primary vascular cylinder of a medium sized branch of *L. Harcourtii*. *c*, *c*, projecting points of peripheral tracheæ; *c'*, *c'*, leaf-traces. C.N. 381. × 25	5 and 8
3	6	Part of a similar section to fig. 8, but from the vascular cylinder of a very young branch. *c*, *c*, projecting points; *c'*, *c'*, leaf-traces. C.N. 380 *a*. × 37 . .	10
5	7	A representation of my largest specimen of *L. Harcourtii*, from which the section, fig. 3, was cut, and showing on the surface between the letters *x*, *x'* the oblong tubercles, *ff*, of the prosenchymatous zone of the cortex through which the leaf-traces reach the leaves. Nat. size. C.N. 380*	8, 9, and 10
2	8	Transverse section of a leaf-trace just entering the middle cortex. *a*, tracheæ of the xylem; *b*, phloem elements; *c*, area from which most of the tissues have disappeared; *d*, cortical cells. C.N. 1596. × 120	10
2	9	Longitudinal section of the leaves and cortex of a young twig of *L. Harcourtii*. *e*, leaf-traces passing through the middle cortex *d*; *e*, prosenchymatous zone; *f*, outer cortex; *g*, leaves. C.N. 380 *f*. × 4	5, 7, and 10
2	9A	Similar section to fig. 12, but with rather more typical leaf-forms. C.N. 380 *l*. × 4	7
2	10	Part of the cortex of the Cabinet specimen 380 *e*, enlarged 15 diameters. *c*, *c*, leaf-traces; *d*, middle cortex; *e*, prosenchymatous zone; *f*, outermost cortex; *g*, leaves	8
2	11	Section through a leaf-trace, rather more oblique than fig. 8. *a*, xylem; *b*, phloem; *c'*, area occupied in some sections by delicate parenchyma. C.N. 380 *e*. × 200	10
1	12	Similar section to fig. 11. *a*, xylem; *b*, phloem. C.N. 1596 A. × 370	10

Plate.	Fig.		Page of the memoir where described.
2	13	Tangential section through the prosenchymatous zone of the cortex, intersecting a leaf-trace transversely. *c'*, leaf-trace; *g*, parichnos. C.N. 380*k*. × 37 . .	11
2	14	Transverse sections of a number of leaves of a young twig of *L. Harcourtii*, made near, and parallel to the surface of the outer cortex. At the right hand the section approaches close to the prosenchymatous zone. C.N. 380*k*. × 4.	11
3	15	Sections through the outer portions of some of the leaves of the specimen, Plate 5, fig. 7. Being obliquely tangential to the cortex, the leaves on the left are intersected nearer to their tips than those to the right. Nat. size	12
3	16	Part of a transverse section through a leaf of a young twig of *L. Harcourtii*, made in the plane of the transverse section of the twig. *c*, leaf-trace; *c''*, fan-shaped arrangement of prosenchymatous cells terminating the leaf-trace; *e*, prosenchymatous zone of the cortex. C.N. 380*b*. × 27	12
3	17	Similar section to fig. 16, but made at a little higher plane through the leaf. *c'*, leaf-trace; *g*, *g*, transverse section through the two lobes of the parichnos. C.N. 1596 B. × 24	12
3	18	Another section in nearly the same plane as fig. 17, but at a slightly different angle, crossing the end of the leaf-trace transversely at *c''*, and the subdivided lobes of the parichnos at *g*, *g*. C.N. 1596 A. × 30	12
3	19	A radial vertical section through the cortex and leaf of a young *L. Harcourtii*. *d*, inner cortex; *e*, imperfect prosenchymatous zone; *c*, leaf-trace, with phloem and xylem; *g*, part of a lobe of the parichnos; *h*, peripheral portion of the adenoid organ. C.N. 380*m*. × 13½	12
3	20	A vertical section through a small leaf of *L. Harcourtii*. *h*, the adenoid organ, terminating at the apex of the leaf. C.N. 380*a*. × 30	12

Plate.	Fig.		Page of the memoir where described.
3	21	Similar section to 20, but in which a portion of the parichnos, *g*, terminates below the apex of the leaf. *h*, the adenoid organ; *e*, the imperfectly-developed prosenchymatous cortical zone. C.N. 380*a*. × 30.	12
6	22	A young fructigerous Halonial branch, with its tubercles, *c*, *c*, *c*, arranged in two lateral series, those of one side only being visible. *c'*, *c'*, two internodes, opposite to which the two tubercles of the reverse side are located. C.N. 649 A. Nat. size	14
5	23	Inorganic cast of a fragment of a large *Halonia regularis*, reduced to two-thirds its natural size . . .	14
5	24	Cast of a younger *Halonia regularis*, partly decorticated at its upper surface, but with its opposite one invested by its cortex, *a*. *c*, *c*, the tips of tubercles, in the centre of each of which can be traced what have been the points of organic union with a strobilus. Two-thirds natural size	14
2	25	Vertical section through a branch bearing Halonial or Ulodendroid tubercles of *Lepidodendron fuliginosum*. *a*, *a*, medulla; *b*, primary tracheal cylinder of the branch; *c*, leaf-trace, going off to a leaf; *d*, innermost cortex in direct contact with the medulla: *d'*, middle cortex; *l*, *l'*, special bundle passing outwards to the fructigerous tubercle; *m*, rows of cells from the innermost cortex accompanying the bundle, *l*, in its outward course. C.N. 396. × 5	18
6	25A	Cortex of a *Lepidophloios*, with rows of Ulodendroid fructigerous scars, arranged as in *Halonia regularis*. *c*, *c*, the central points of each tubercle, where the strobilus was organically united to the branch or stem. C.N. 649 B. Nat. size	14 and 16
1	26	Transverse section of a young branch, *A*, of *L. Harcourtii*, giving off two lateral arrested fructigerous branches, *B* and *C*. *A*, *a*, medulla of the primary branch; *b*, primary tracheal cylinder; *c*, leaf-trace; *d*, middle cortex; *e*, prosenchymatous zone; *f*, outer	

Plate.	Fig.		Page of the memoir where described.
		cortex; *g*, leaves. *B*, *l'*, central tracheal bundle of the fructigerous branch; *m'*, inner cortex of the same. *C*, a still younger fructigerous branch; *l*, its tracheal bundle; *m*, its investing cortex; *e*, its prosenchymatous zone; *g*, its leaves. C.N. 380*b*. × 4	19
6	26A	A *Lepidodendron*, *a*, giving off a shortened branch, *a'*, which supports a large *Lepidostrobus*, *b*. Two-thirds the natural size. C.N. 380*b*	16
1	27	A second transverse section of the conical fructigerous branch, *B*, of fig. 26, made nearer to its apex. *l'*, its central tracheal bundle; *m*, inner investing cortex; *, line of junction with the primary branch. C.N. 380*a*. × 4	19
5	27A	A *Lepidostrobus*, developed from the extremity of a pendulous twig, *a*	16
1	28	The central structures of *B* of fig. 26, enlarged 40 diameters. *a*, central bundle of tracheæ; *b*, cells of innermost cortex; *c*, *c'*, leaf-traces. C.N. 380*a*. × 40	19
3	29	Longitudinal section of a very young twig of *L. Harcourtii*, giving off an arrested fructigerous branch. *A*, the primary branch. *B*, the fructigerous one; *a*, primary strand, consisting of medulla and primary tracheal cylinder; *b*, tracheal strand given off to the fructigerous branch, *B*; *c*, vacant space, from which the inner cortex has disappeared; *c'*, leaf-traces; *d*, middle cortex; *e*, prosenchymatous zone; *f*, outer cortex; *g*, leaves. C.N. 1596 D. × 4½	19 and 23
4	29*	Part of the tracheal strand, *b*, of fig. 29, enlarged 40 diameters. *c*, tracheæ; *c'*, an investing cellular zone of doubtful homology. C.N. 1590 D. × 40. . .	23
4	30	Transverse section of a branch of a *Lepidophloios*, which bears large bilateral fructigerous tubercles. *a*, medulla; *b*, primary tracheal cylinder; *d*, middle cortex; *e*, prosenchymatous zone; *f*, outer cortical parenchyma; *g*, leaves. C.N. 1955. × 2⅓ . . .	20

Plate.	Fig.		Page of the memoir where described.
3	30A	The prosenchyma, of fig. 30, showing the active meristemic conditions at *b*; by which the cells of the outer cortex, *c*, are being converted into the prosenchymatous fibres, *a*. × 100	20
4	31	The leaf, *g′*, of fig. 30. *c*, leaf-trace; *g*, *g*, portions of the lobes of the parichnos; *e*, prosenchymatous zone of the cortex; *x*, portion of the leaf, eaten by some phytophagous animal which has left its Copros in the cavity. C.N. 1955. × 7	21
4	32	Similar section to 31, but made in a rather superior plane. *c*, portion of the leaf-trace; *g*, *g*, two lobes of the parichnos, uniting into one at *g′*; *e*, prosenchymatous zone of the cortex. C.N. 1956. × 7 .	21
4	33	Vertical longtitudinal section through a leaf. *b*, its base; *a*, its apical portion; *c*, its leaf-trace; *g*, fragment of a parichnos; *h*, the inner extremity of the adenoid organ, prolonged outwards. C.N. 1962. × 10	21
4	34	A similar section to fig. 33, but passing a little on one side of the centre of the leaf; it intersects, at *g*, one of the lobes of the parichnos, following the curvature of the upper border of the leaf. The latter, *m*, consists chiefly of prosenchyma. C.N. 1963. × 10 . .	21
4	35	Vertical section through the base of a leaf. *c*, part of the leaf-trace; *g*, *g*, the two lobes of the parichnos, uniting into one at *g′*, where it rests upon the leaf-trace; *e*, the prosenchymatous zone of the cortex, through which the inner extremity of the parichnos, *g′*, is prolonged. The adenoid organ is cut across at *h*. C.N. 1946. × 13	22
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Plate.	Fig.		Page of the memoir where described.
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4	38	Vertical longitudinal section through a leaf-trace. *b*, cortex above, and *b′*, below the leaf-trace; *c*, upper prosenchymatous portion of the leaf-trace; *c′*, tracheal bundle of the leaf-trace; *c″*, *c″*, spiral cells in the mezophyl of the leaf immediately surrounding the leaf-trace. C.N. 1957. × 125. . .	23
4	39	Transverse section through the base of one of the fructigerous tubercles of the *Lepidophloios*, showing the tracheæ, *a*, of its vascular bundle. C.N. 1976. × 33	23
7	40	Section like fig. 39, but through the cortex of another biserial fructigerous branch, in the centre of which is the tracheal bundle of the tubercle surrounded by zones of the innermost cortex. *l*, tracheal bundle; *m* and *k*, innermost cortex. C.N. 645 D. × 10 .	23
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7	42	The upper portion of fig. 41, enlarged 17 diameters. *a*, *a′*, two of the sporangiophores of the strobilus; *b*, portion of a sporangium with some spores; *c*, part of the wall of the sporangium. C.N. 624*e*. × 17 .	25
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Plate.	Fig.		Page of the memoir where described.
8	45	Lateral view of a spore, *a*, enclosed within its mother-cell, but with most of its surrounding sterile cells removed. *b*, narrow zone of attachment of the contracted inner margin of a sterile sister-cell to the central fertile one. C.N. 630. × 280	25
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9	49	A single spore, enclosed in its mother-cell, but with a superficial triangular line which has some relation to the triangular cavity, *a*, of fig. 44. C.N. 628. See also 629	25
7	50	A fine vertical section through the centre of a *Lepidostrobus* of *L. Spenceri*. *b*, its primary tracheal cylinder; *c*, portion of its inner cortex; *d*, its middle and outer cortex; *e*, sporangiophores; *f*, sporangia; *f′*, sporangial wall enclosing numerous spores. C.N. 624*b*. × $9\frac{1}{2}$	25
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8	53	*Lepidostrobus* of the *Lycopodites* (?) *longibracteatus* of Morris, with large foliaceous sporangiophores, *b*, and short rounded sporangia at *a*. Nat. size . .	26
8	54	A second specimen, like fig. 53, but showing that the	

Plate.	Fig.		Page of the memoir where described.
		Lepidostrobus was terminal at the end of an elongated branch, like fig. 30A, Plate 5. Nat. size . .	26
8	55	Upper part of a vertical section of a *Lepidostrobus*. × 7	27
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9	57	Longitudinal section of a homosporous *Lepidostrobus*. C.N. 1614. × 4	27
9	58	A fine transverse section of an apparently homosporous *Lepidostrobus* from Oldham—*L. Oldhamium*, WILL. C.N. 568. × 3½	27
1	59	Centre of fig. 58. *a*, medulla; *b*, primary tracheal cylinder; *c*, vascular traces going to the sporangiophores, fig. 58, *d*; *e*, sporangia. C.N. 568. × 15.	27
8	60	One of the vascular bundles, *c*, of fig. 59, further enlarged. C.N. 568	27
6	61	Portion of a strobilus identical with fig. 58. The sporangia to the left, *a*, are intersected tangentially, and those to the right, *a′*, radially. *a*, *a′*, sporangia; *b*, *b′*, sporangiophores. C.N. 574. × 4	28
6	62	A restoration of the right-hand portion of the fig. 61. *a*, the central axis of the strobilus; *a′*, medulla; *a″*, the primary tracheal cylinder; *b*, *b′*, the sporangiophores; *b″*, the vascular bundle of the sporangiophore; *c*, microspores in the sporangium, *c′*; *d*, *d*, cortex of the central axis of the strobilus . .	28
9	63	A fragment of the *Lepidostrobus* figured in Memoir, Part X., Plate 15, fig. 8, with macrosporangia at *a*, *b*, *c*, and microsporangia at *d*, *e*, and *f*. C.N. 587 A. × 200	28
9	64	An oblique vertical section, passing a little on one side of the apex of a *Lepidostrobus* at its upper portion, and still more laterally, crossing the outer portions of the sporangiophores at its lower end. C.N. 577. × 13	29

Fig. 3.

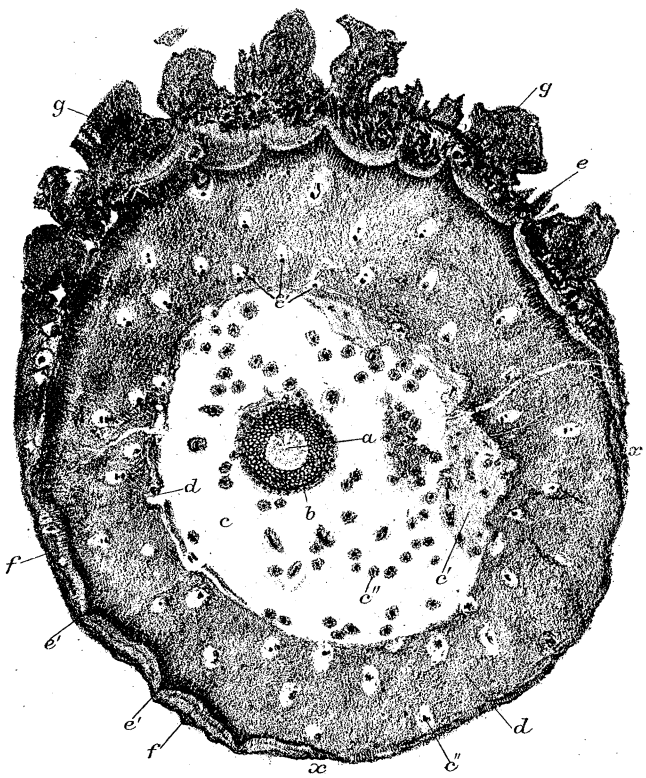


Fig. 2a.

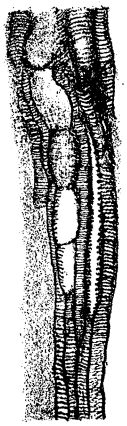


Fig. 1.

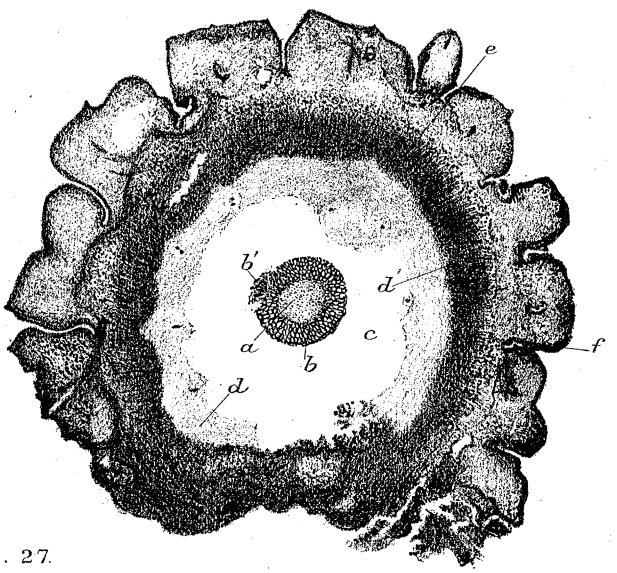


Fig. 27.

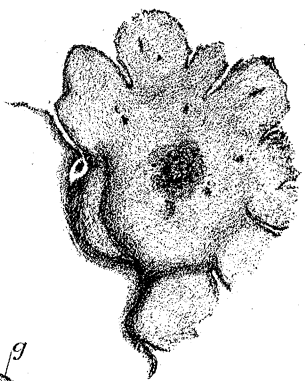
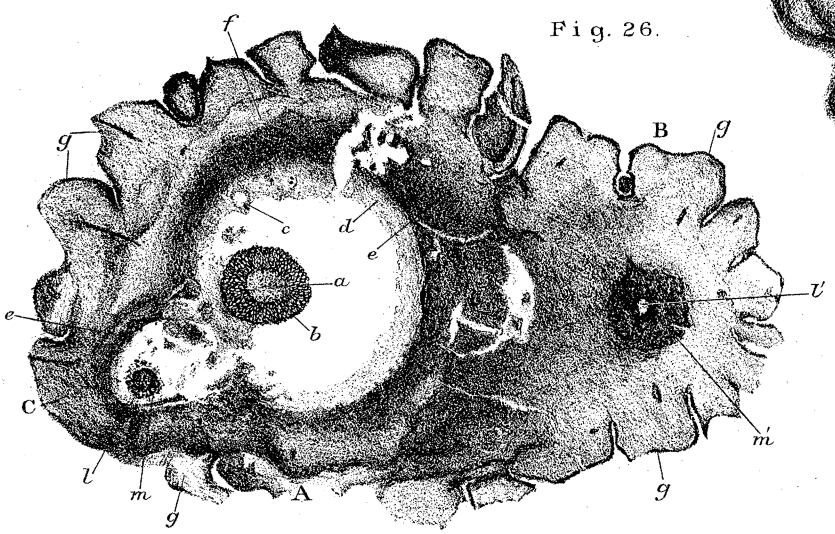


Fig. 26.



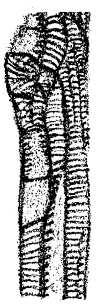


Fig. 2.

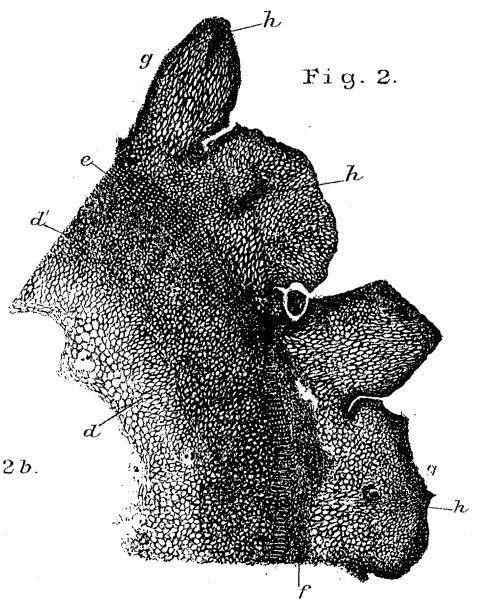


Fig. 2b.

Fig. 4.

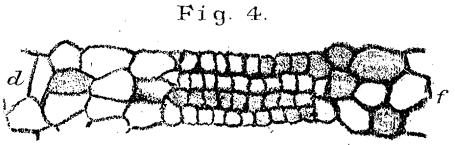


Fig. 59.

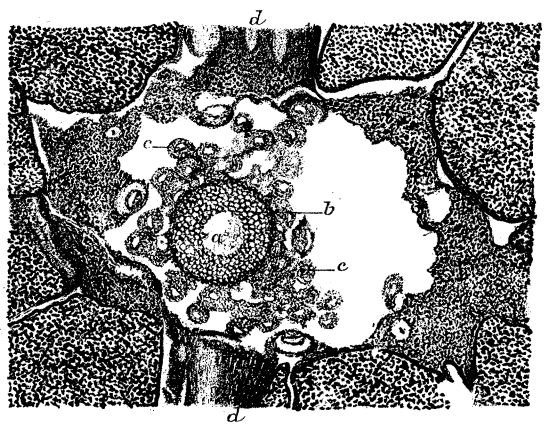


Fig. 12.

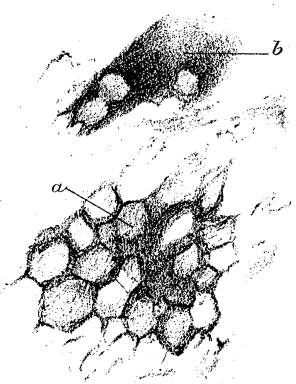


Fig. 28.

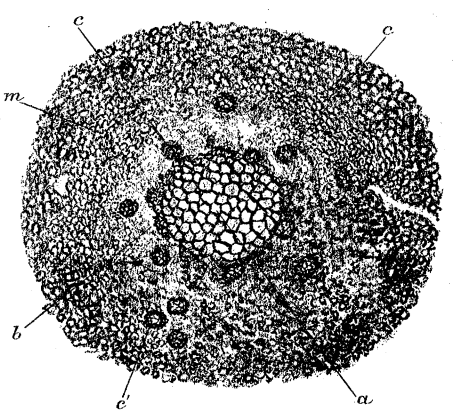


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Fig. 14.

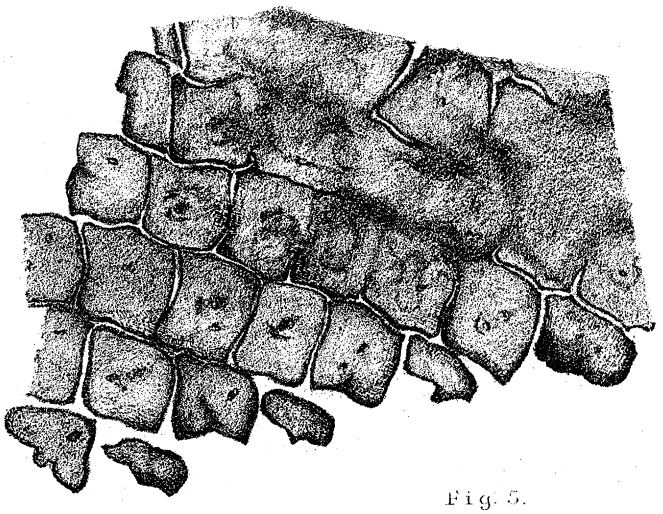


Fig. 5.

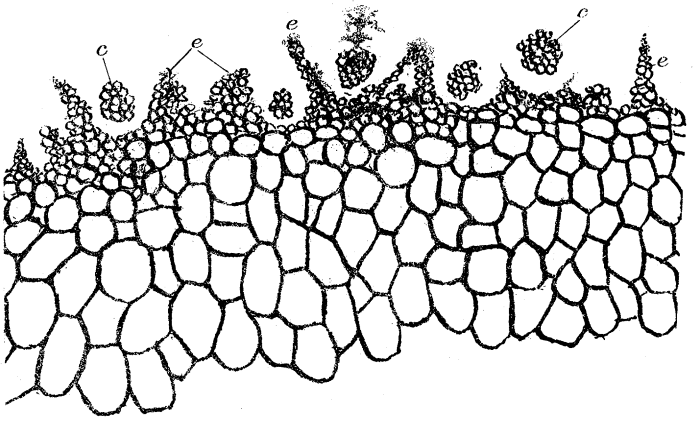
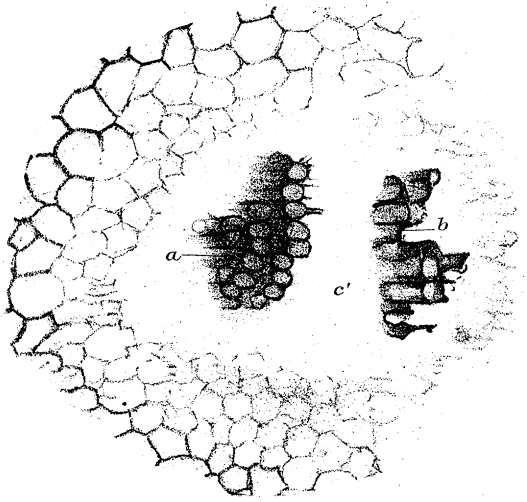


Fig. 8.



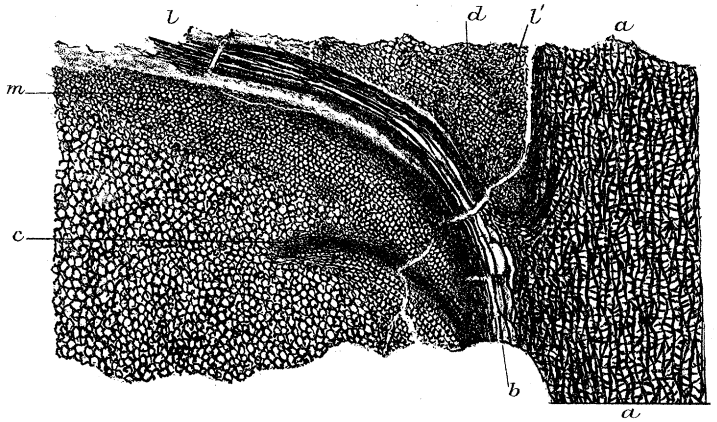


Fig. 25.

Fig. 10.

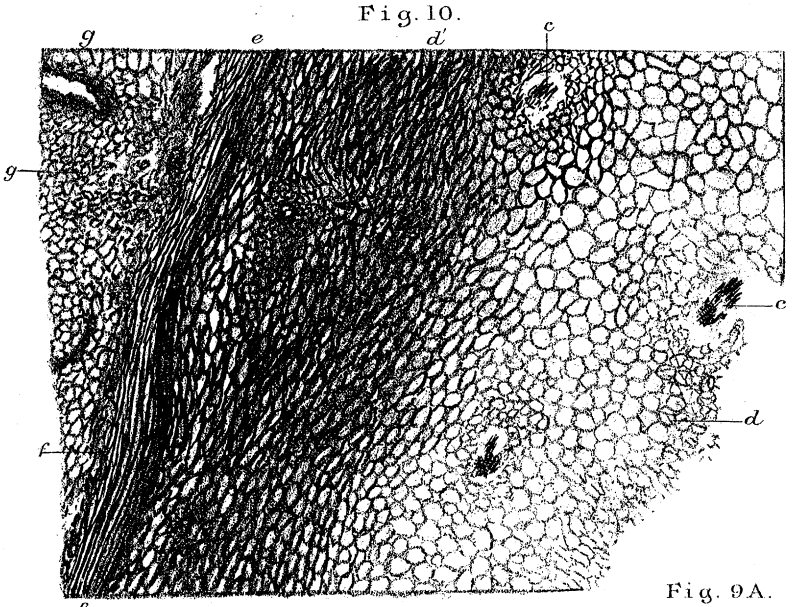
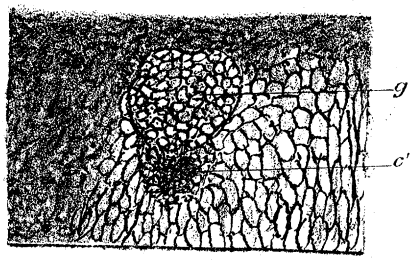
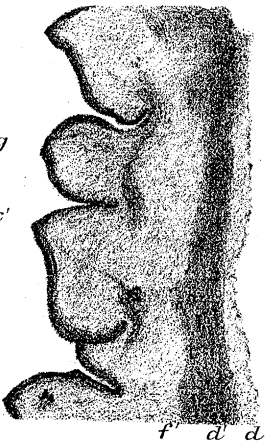


Fig. 9A.

Fig. 13.





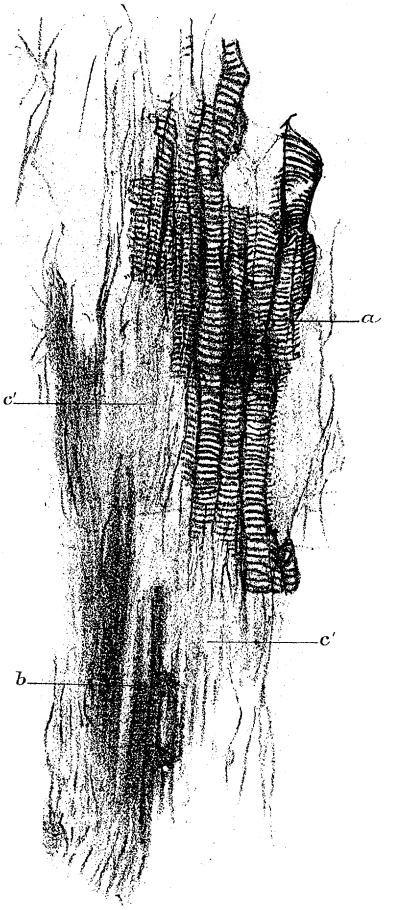


Fig. 11.

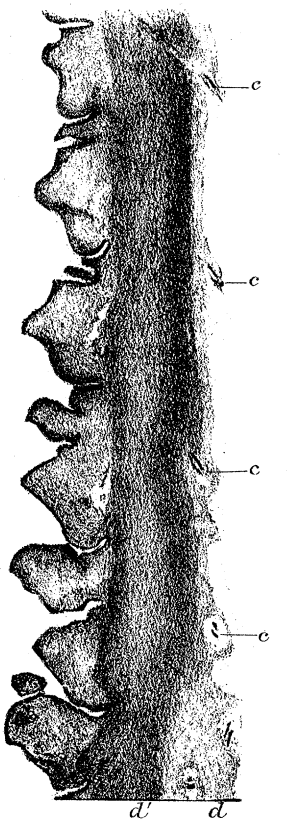


Fig. 9.

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Fig. 6.

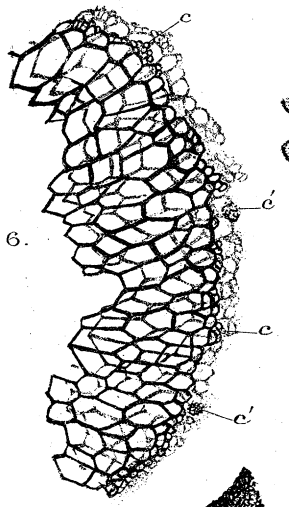
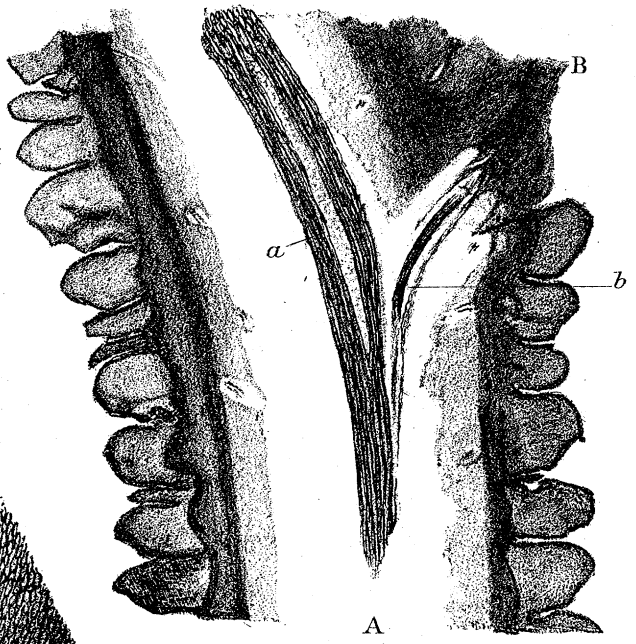


Fig. 29.



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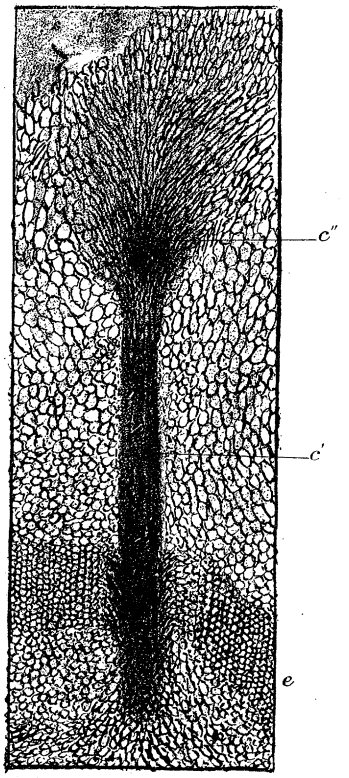

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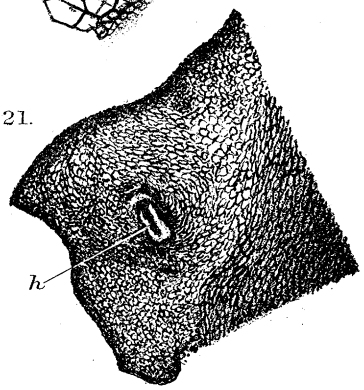

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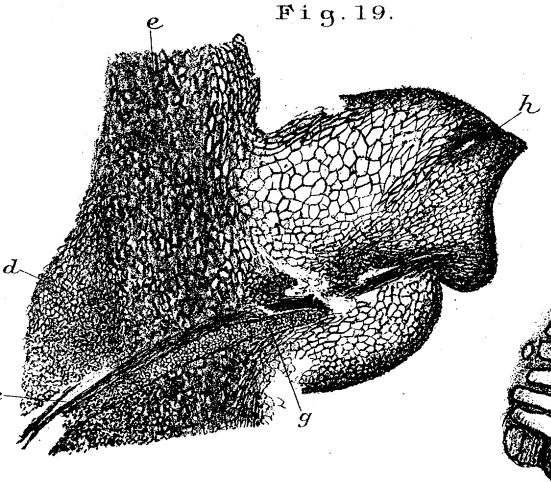

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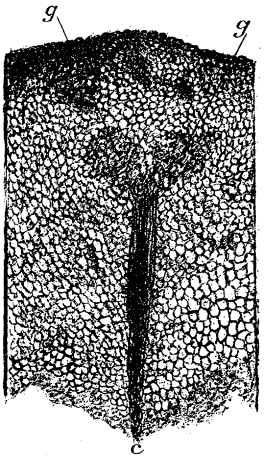

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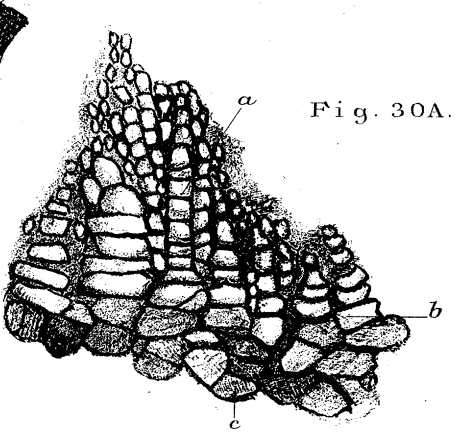

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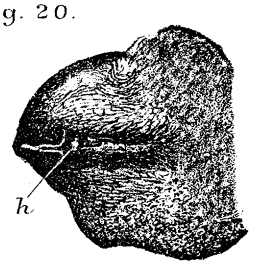

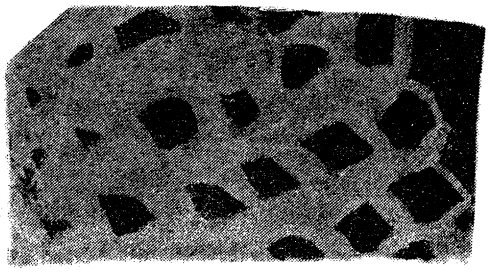

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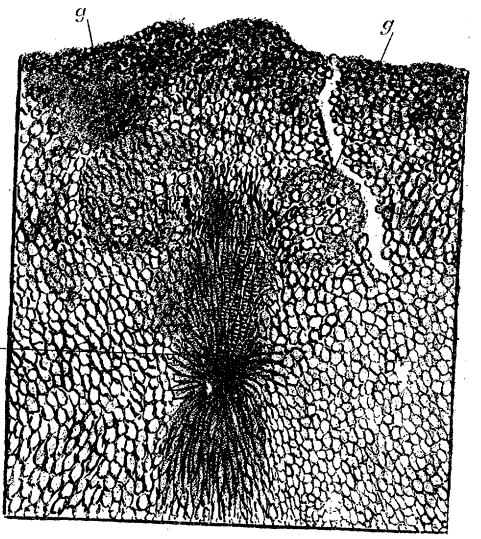

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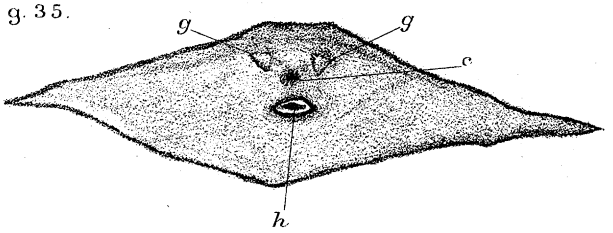

Fig. 18.

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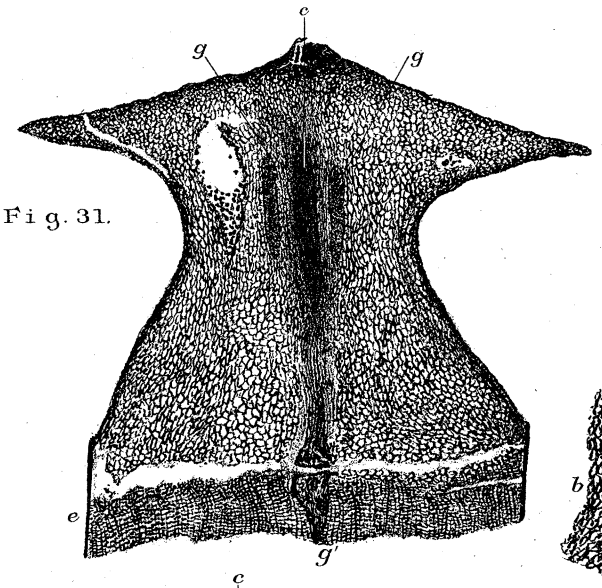

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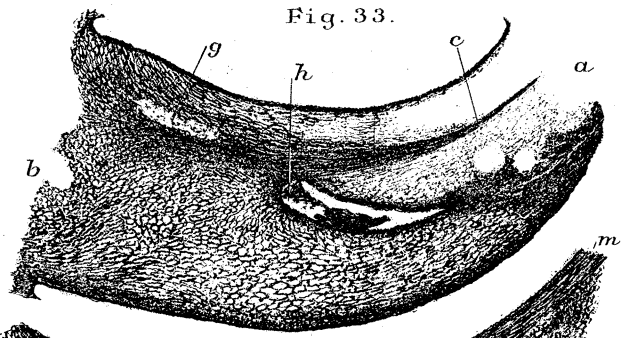

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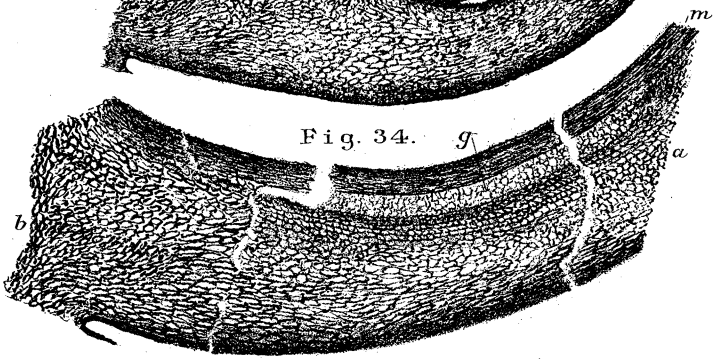
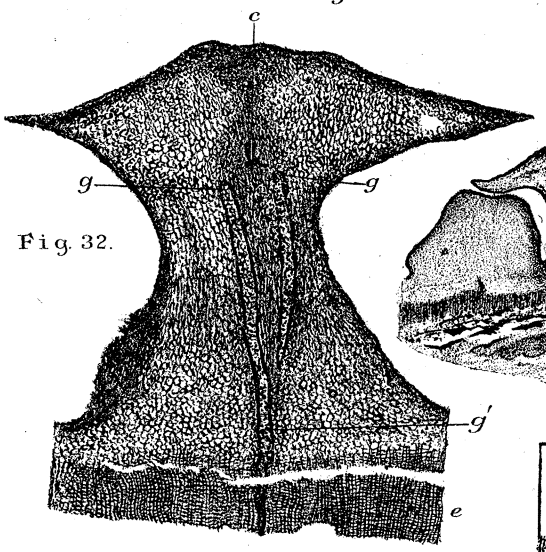


Fig. 34.

Fig. 30.



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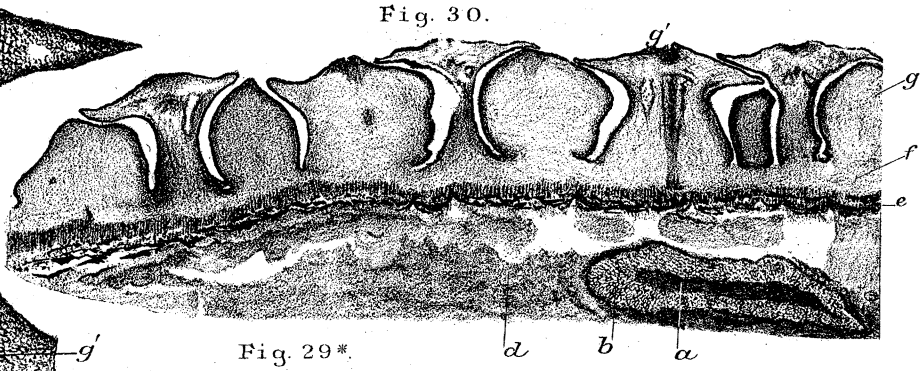
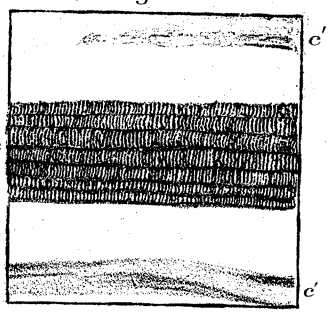
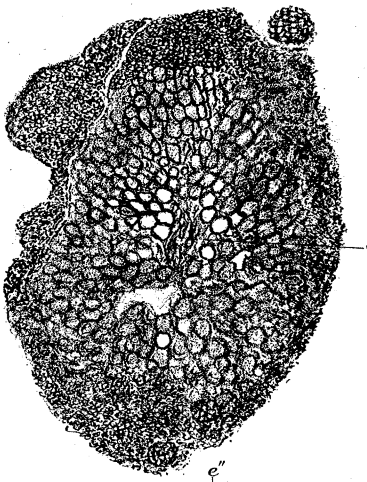


Fig. 29*.





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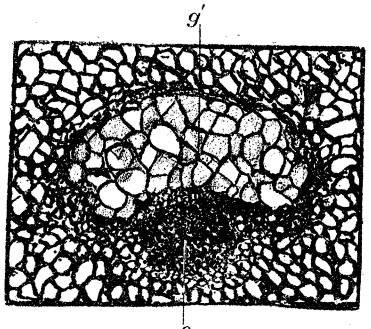

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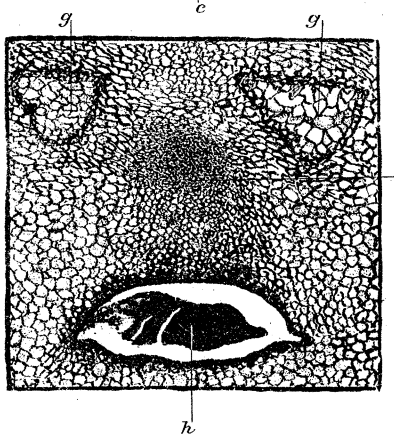

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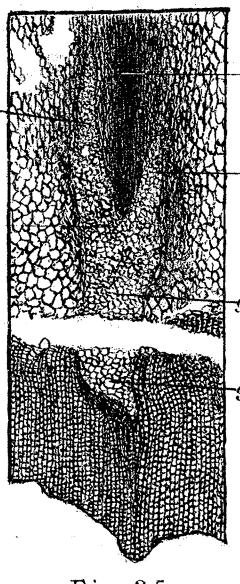

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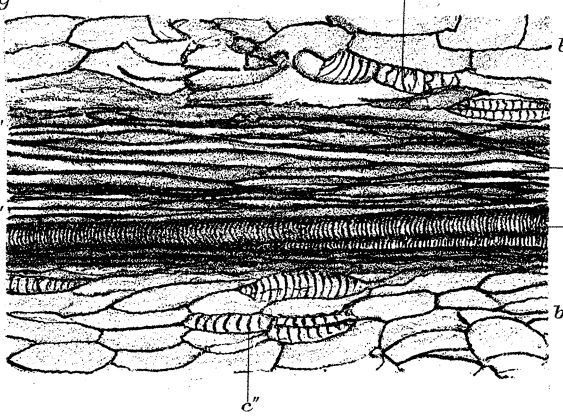

Fig. 38.

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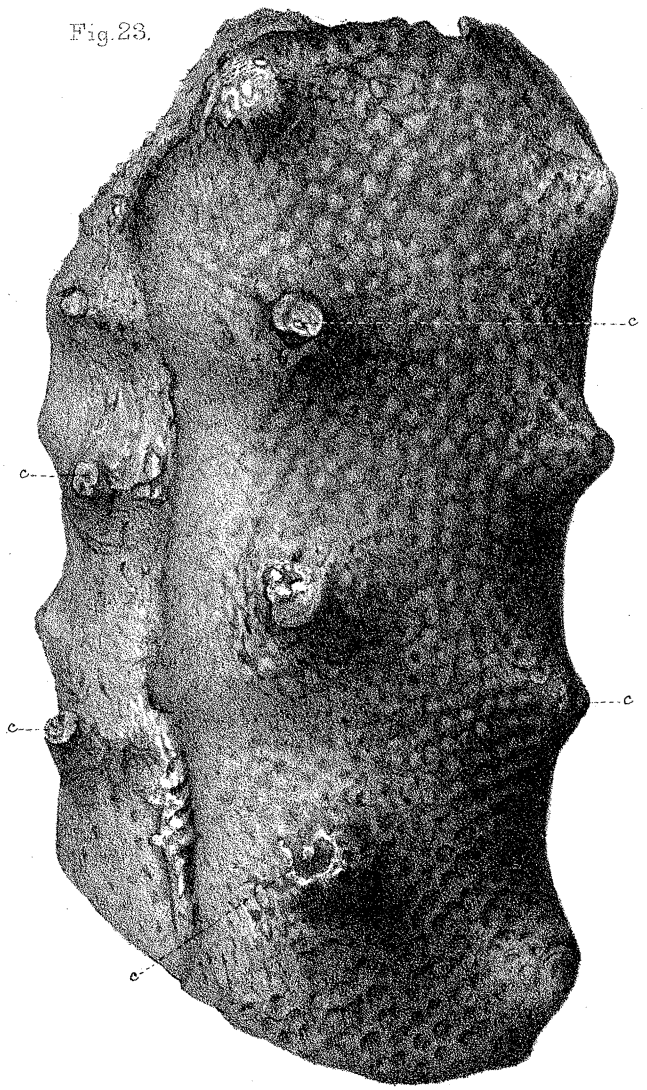
Fig.23.



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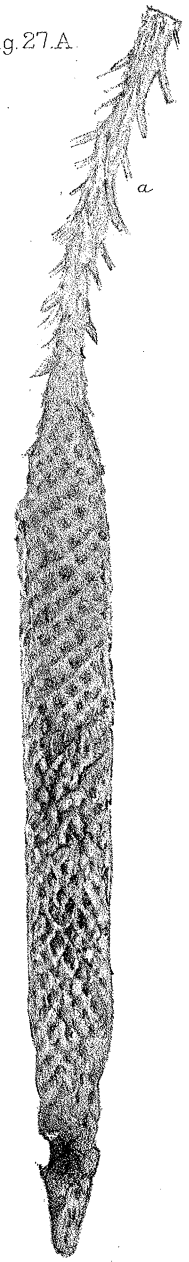

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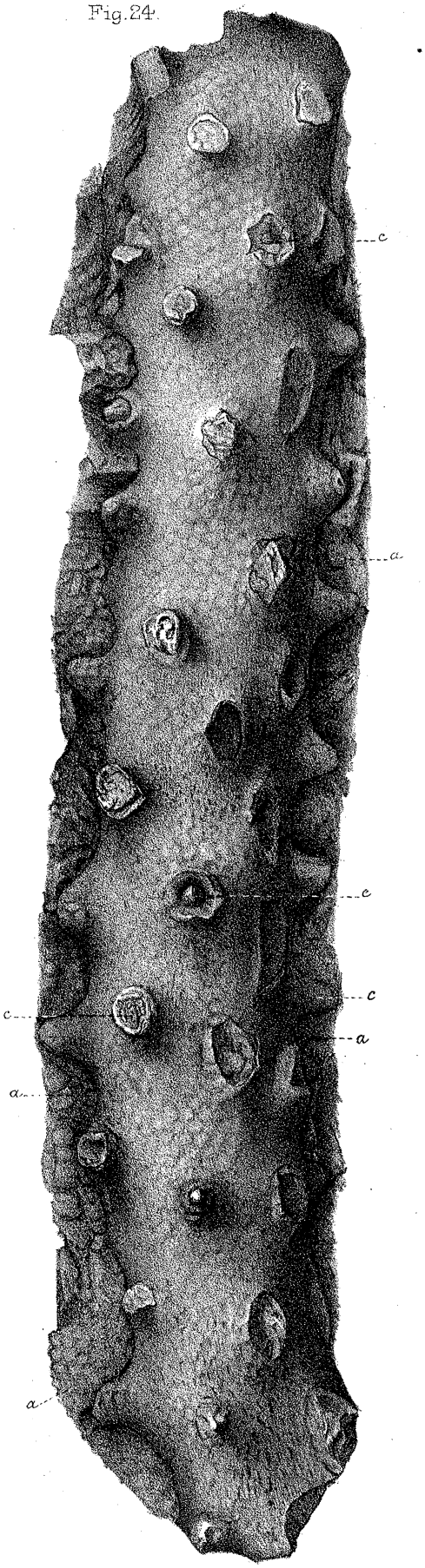

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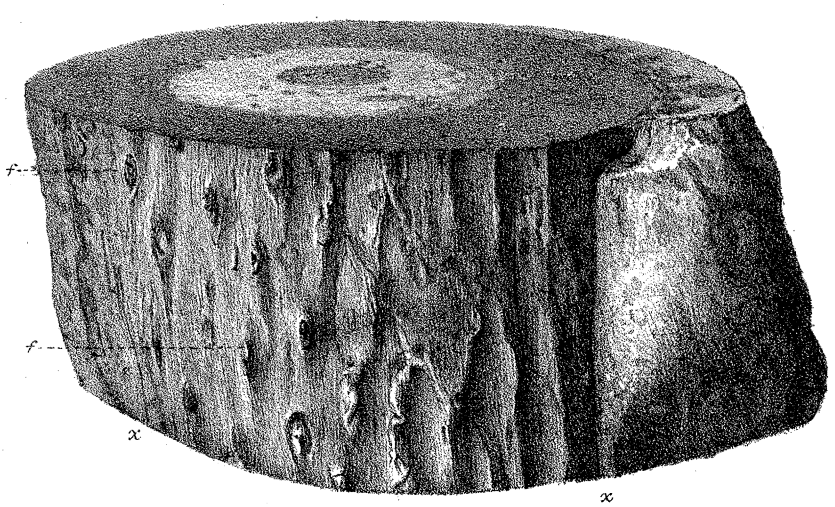

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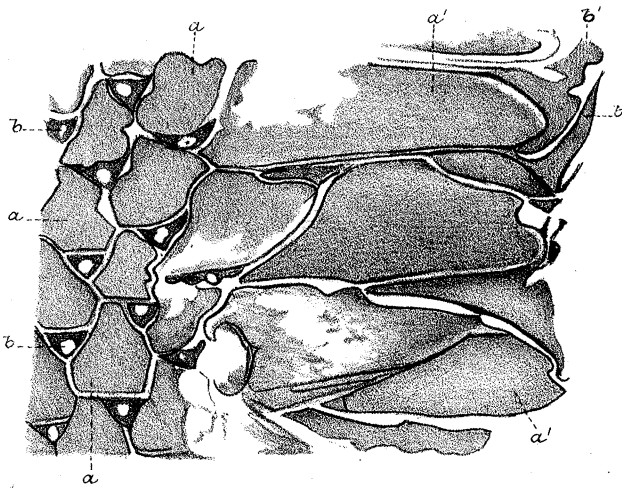


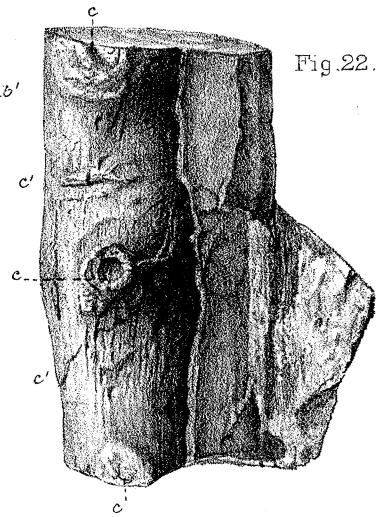
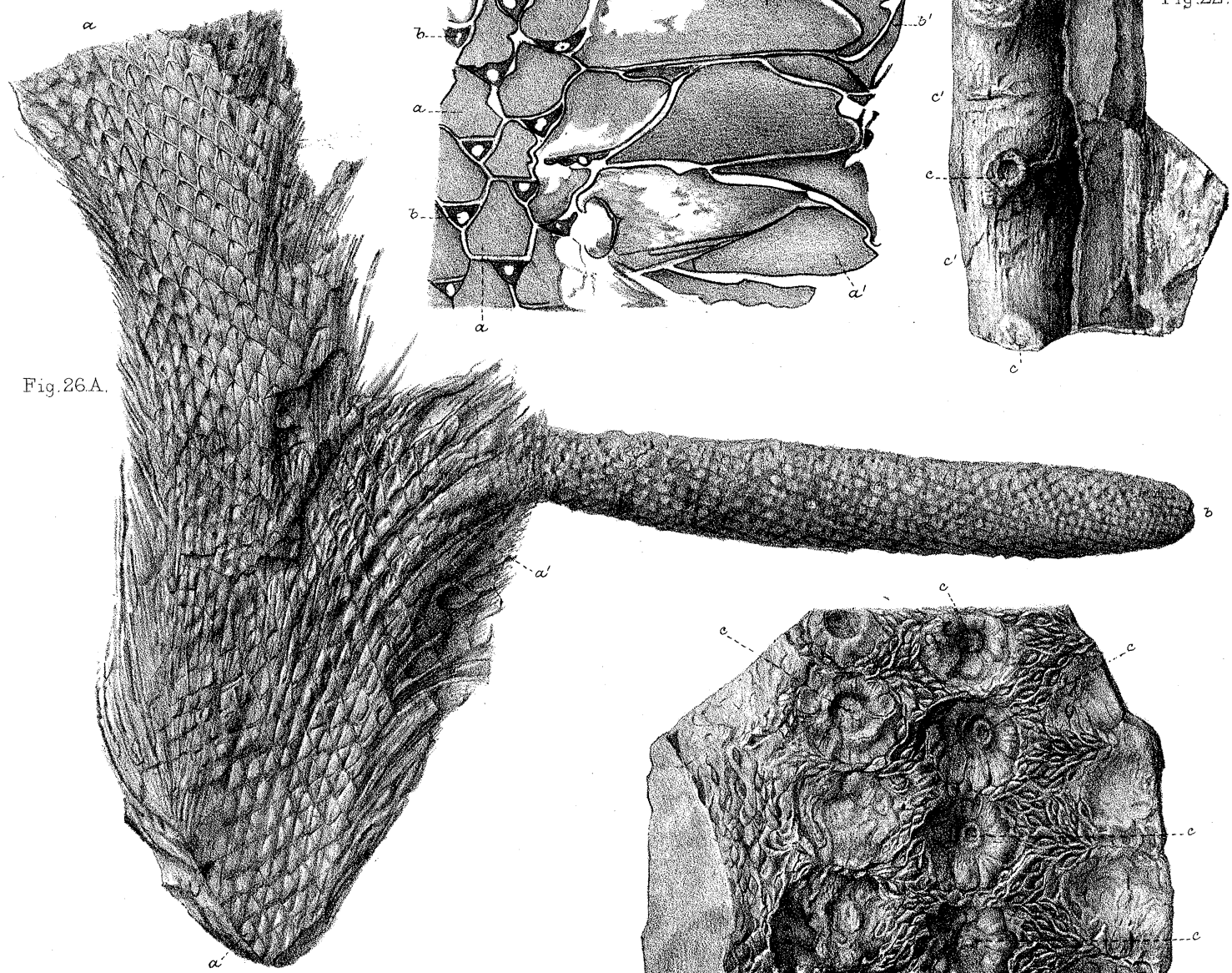


Fig.22.

Fig.26.A.



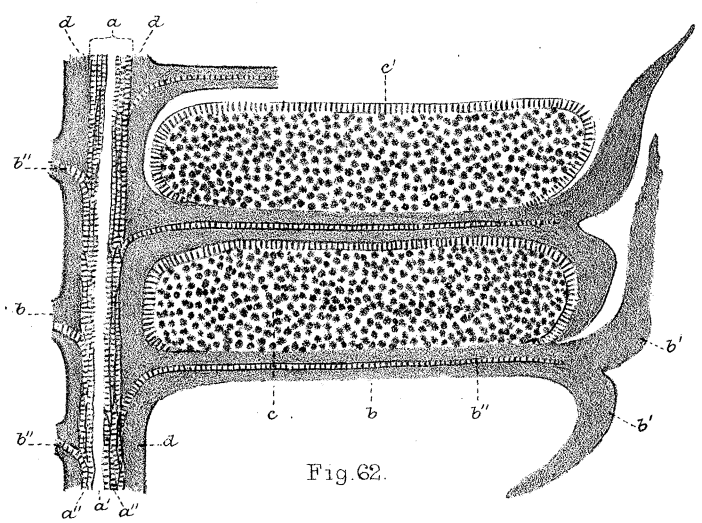


Fig.62.

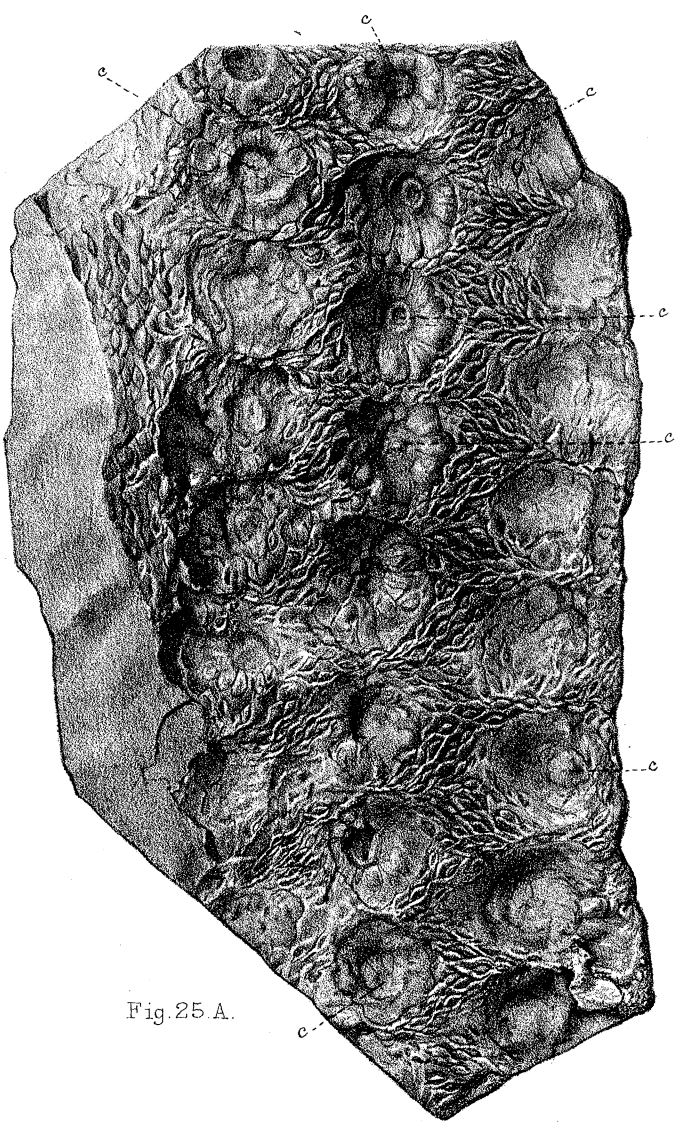
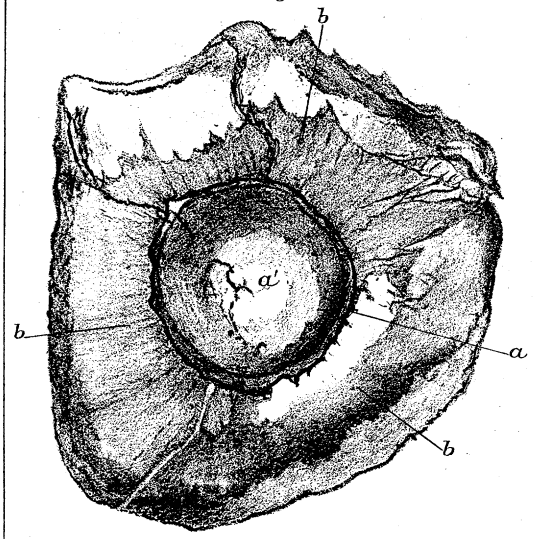


Fig.25.A.

Fig. 43.



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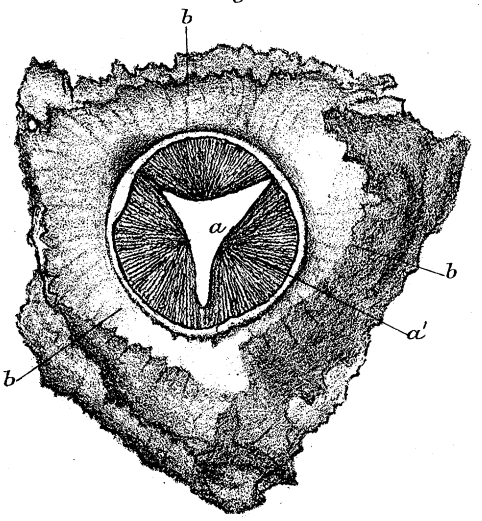
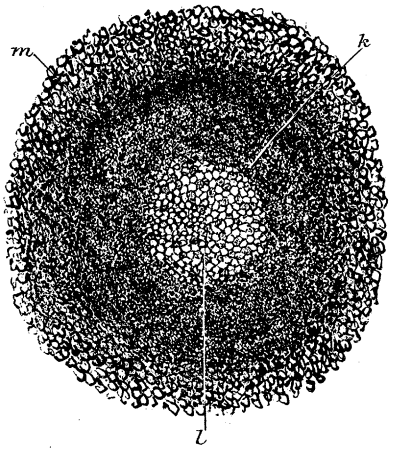


Fig. 40A.

Fig. 40.



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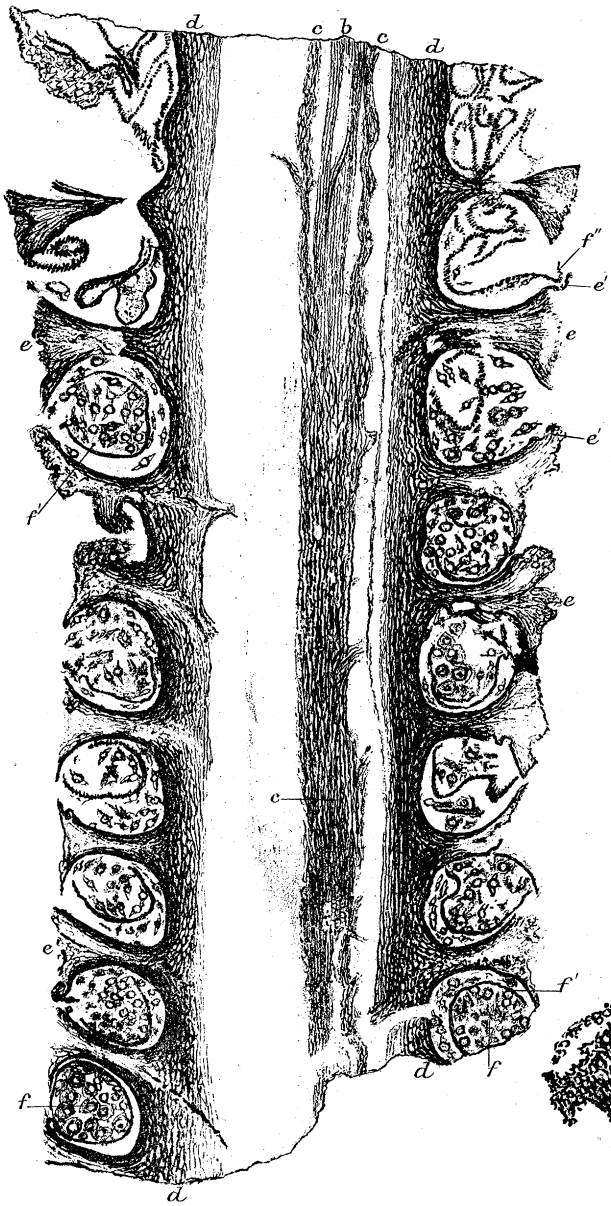

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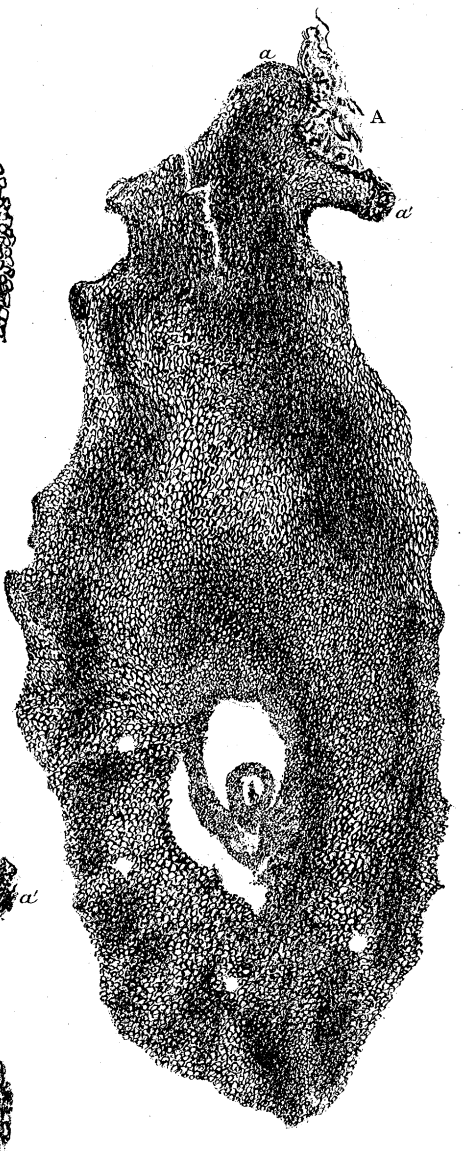

Fig. 41.

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Fig. 52.

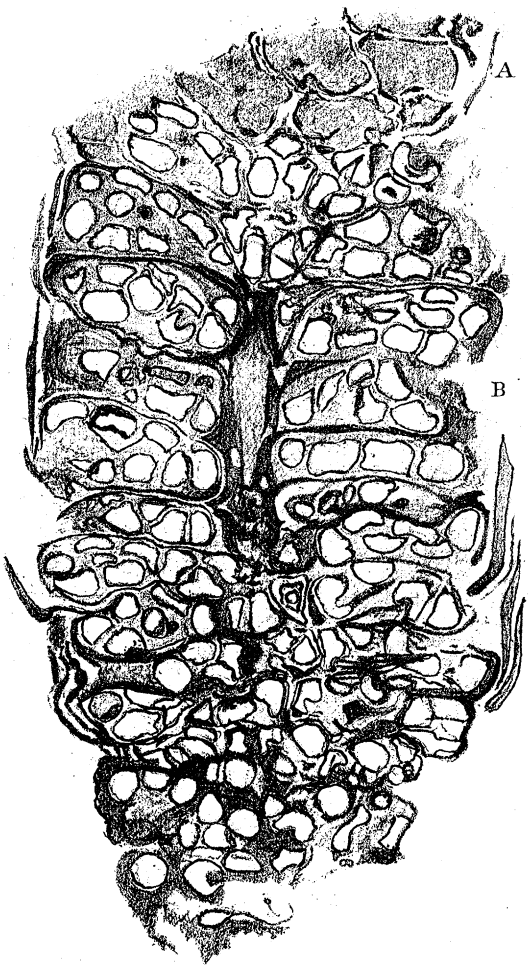
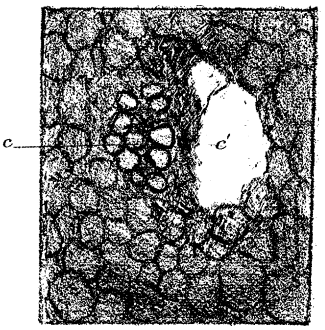


Fig. 55.

Fig. 60.



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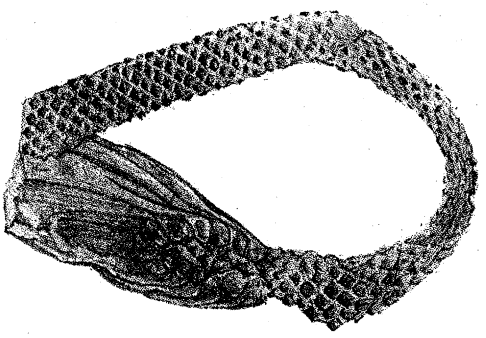

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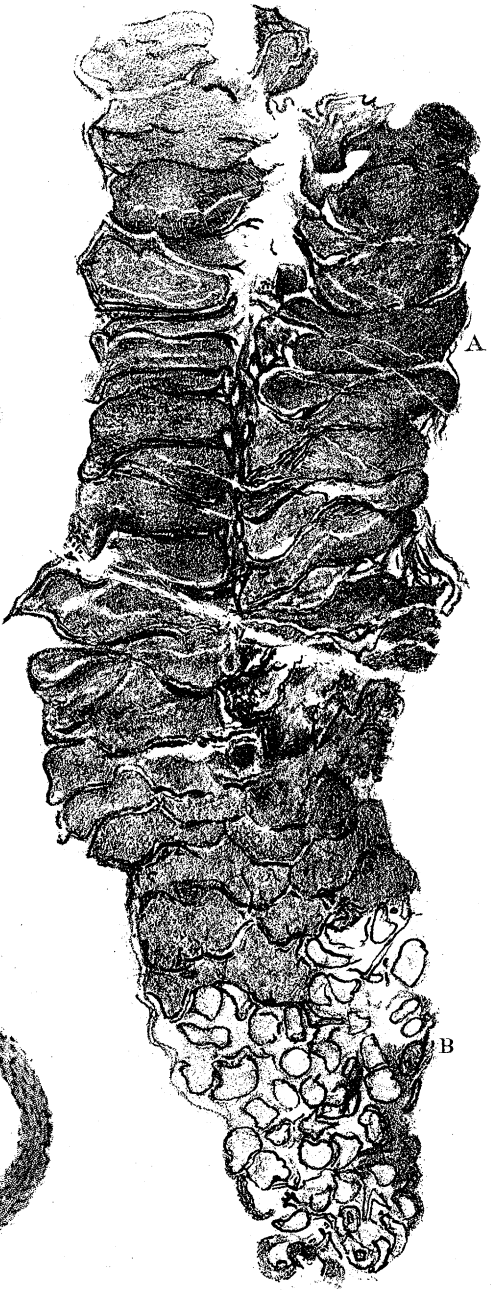

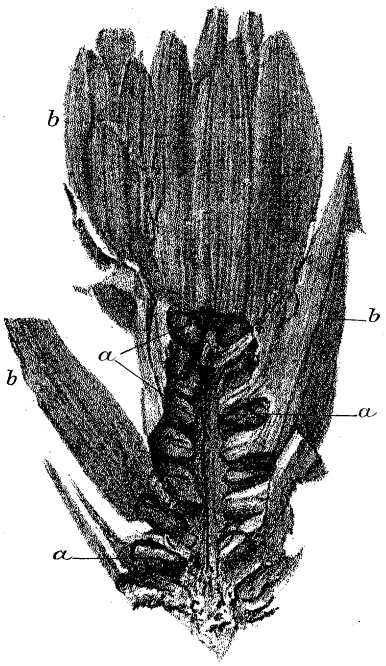

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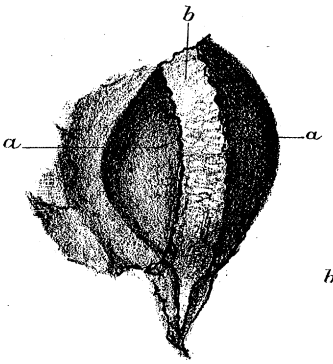

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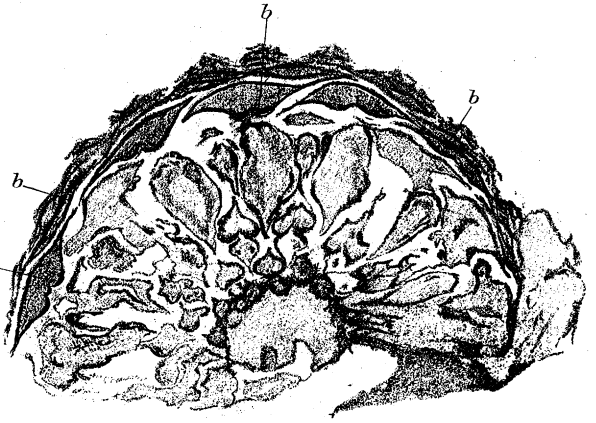

Fig. 56.

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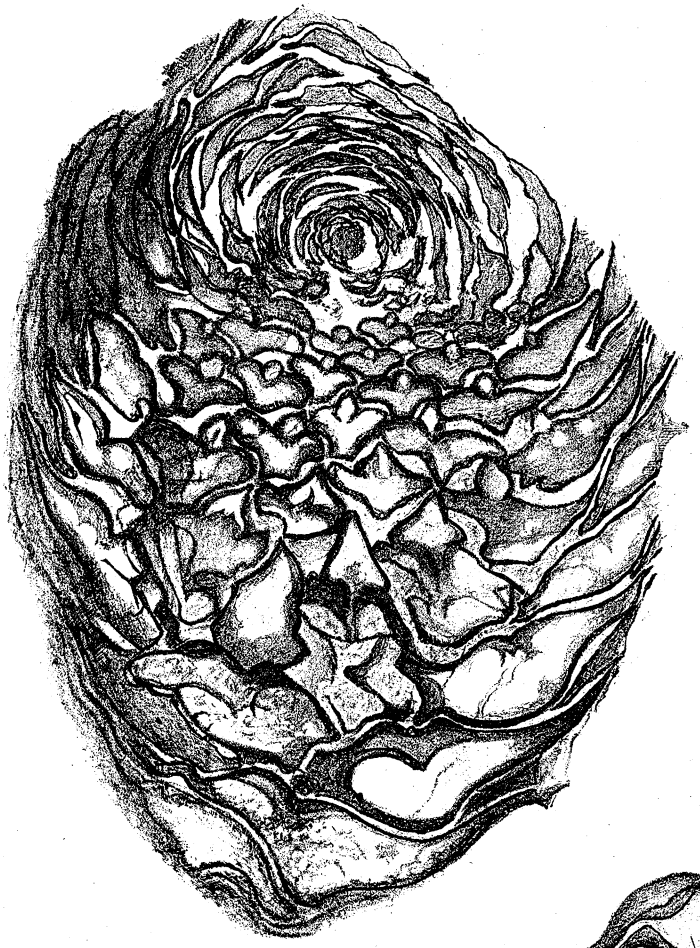
Fig. 64.



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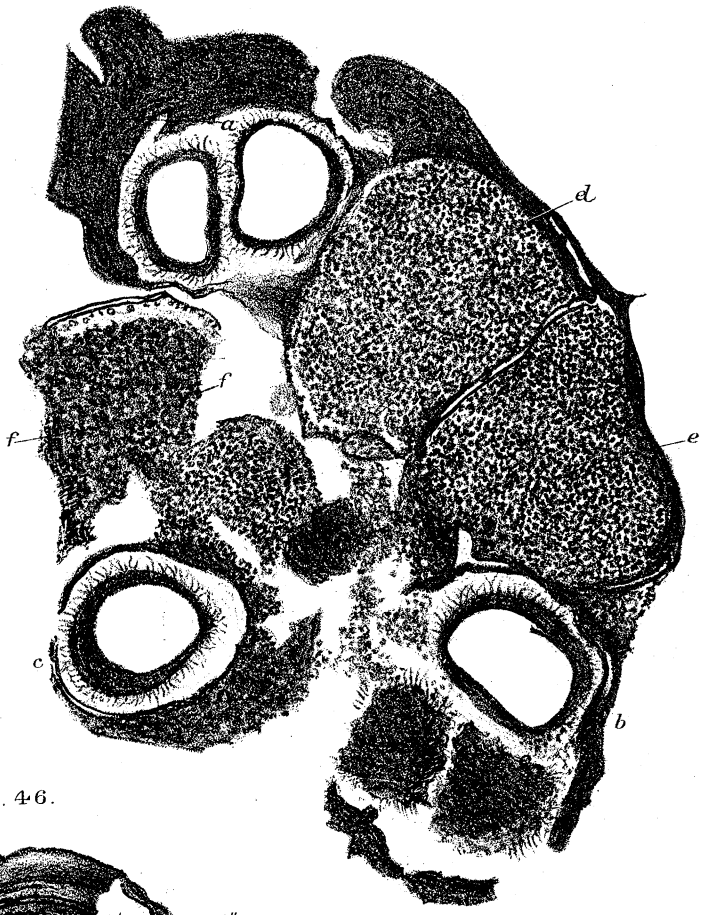

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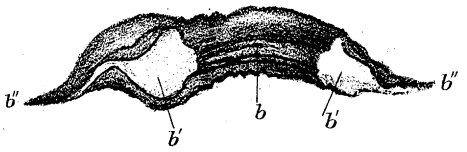

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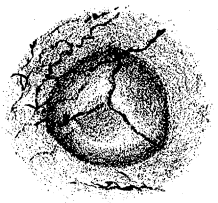

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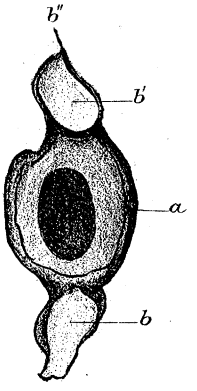

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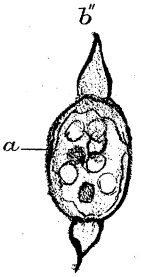

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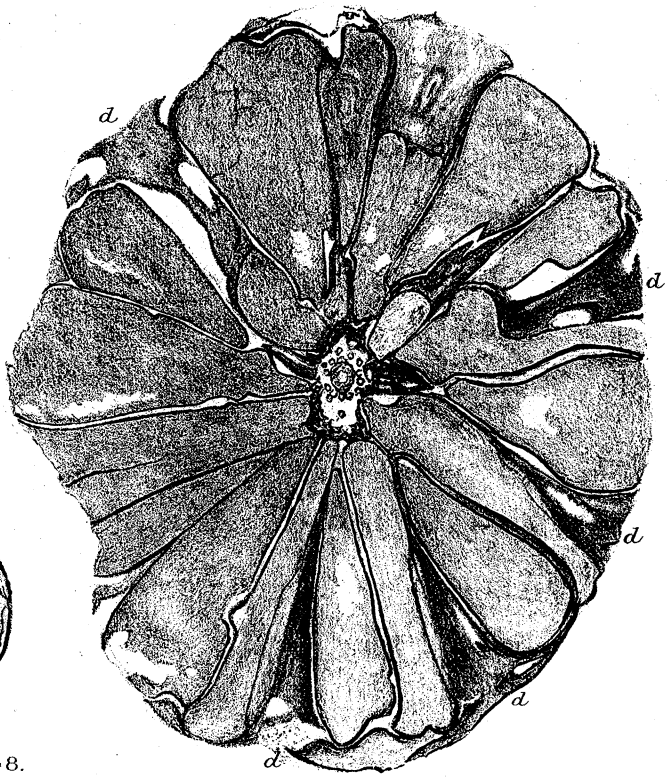


Fig. 58.

Fig. 3.

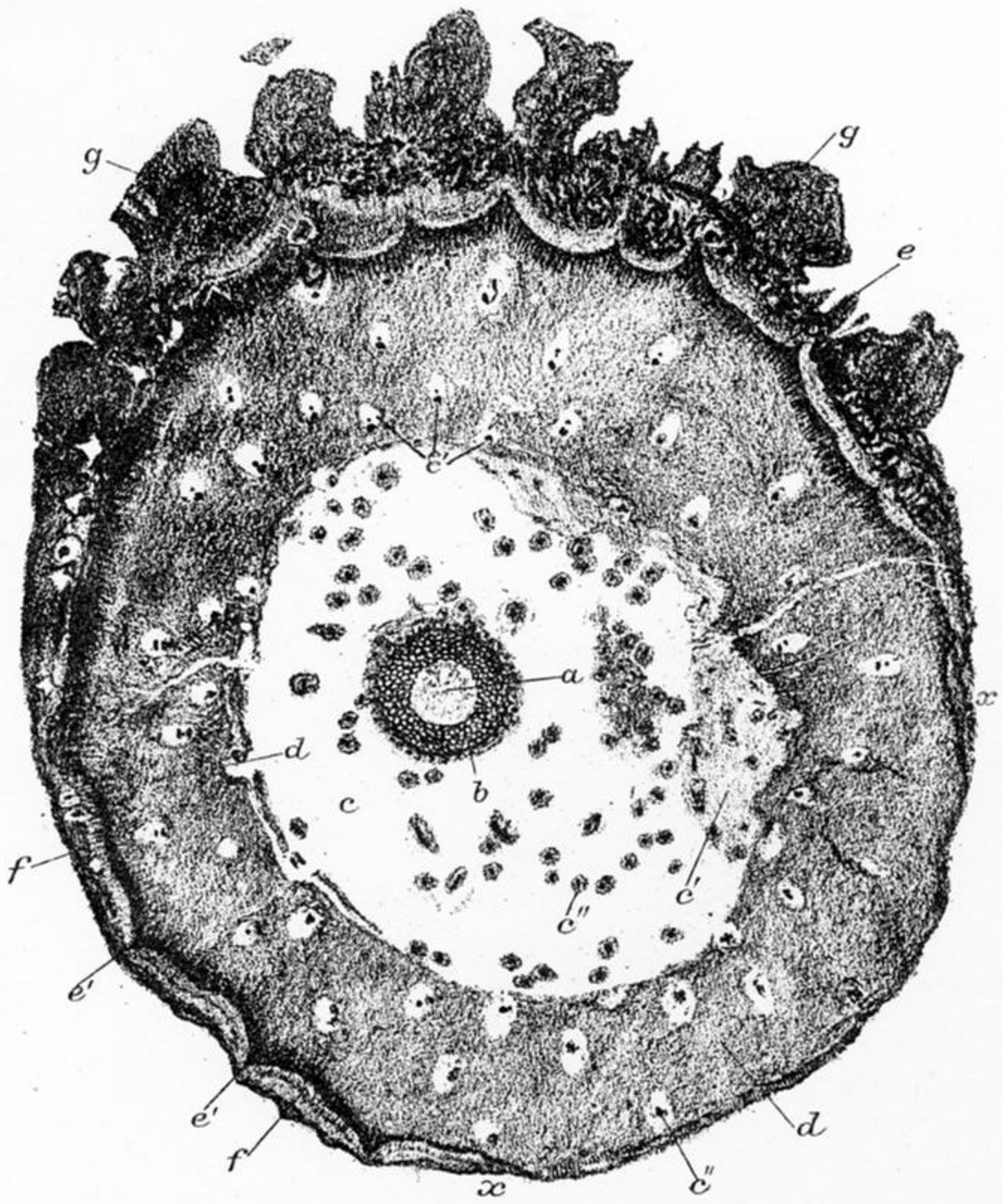


Fig. 2a.

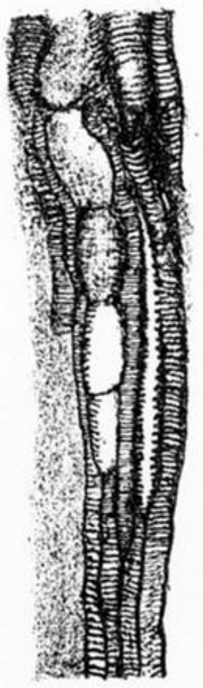


Fig. 1.

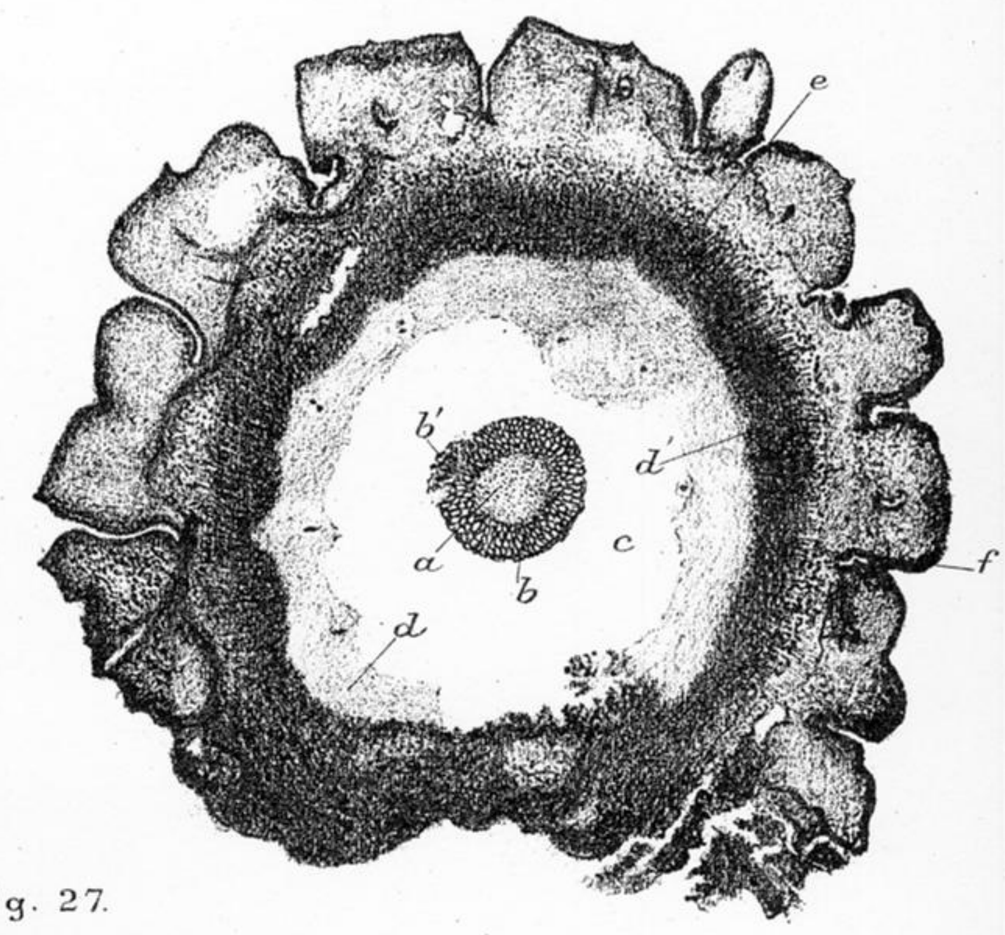
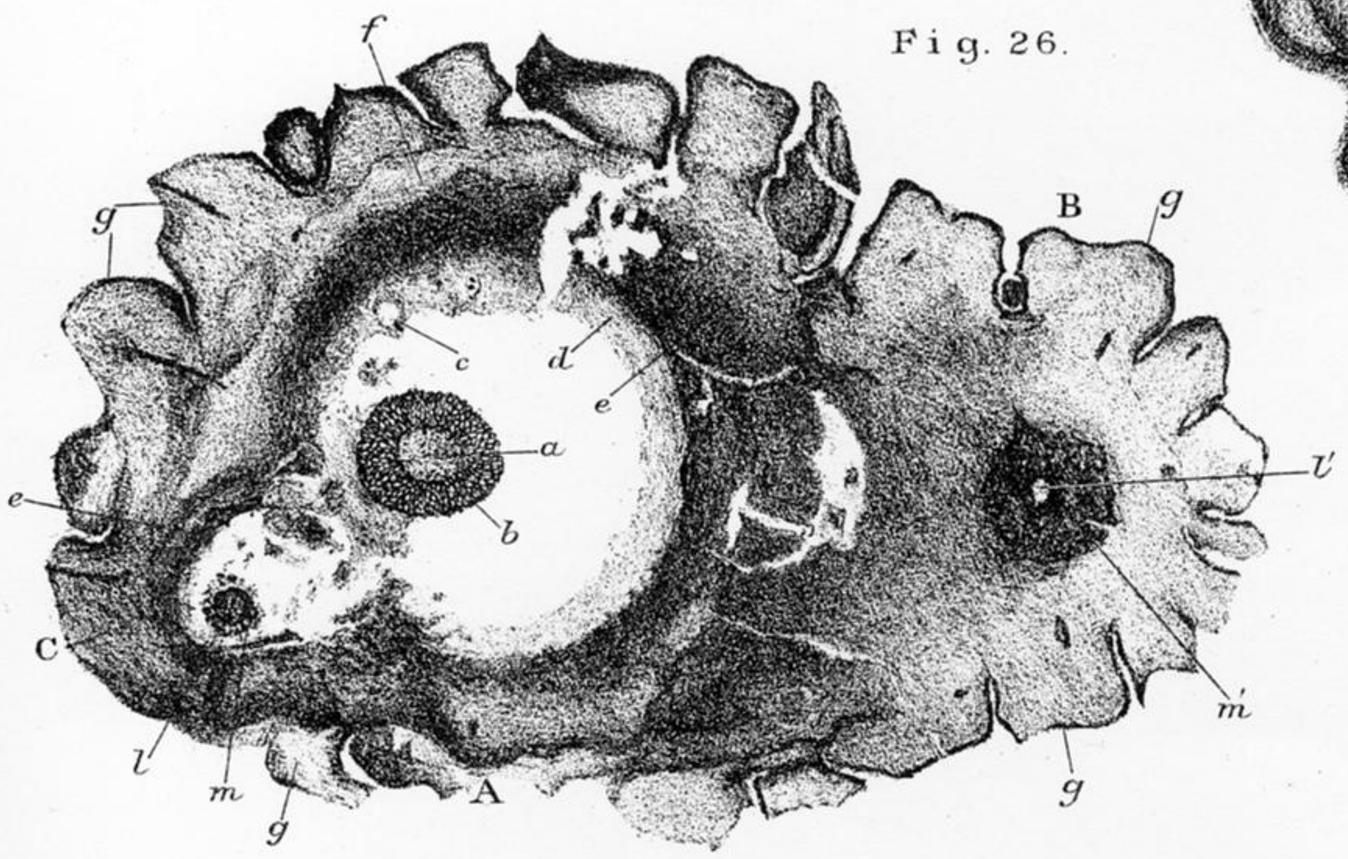


Fig. 27.

Fig. 26.



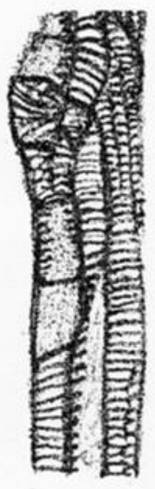


Fig. 2b.

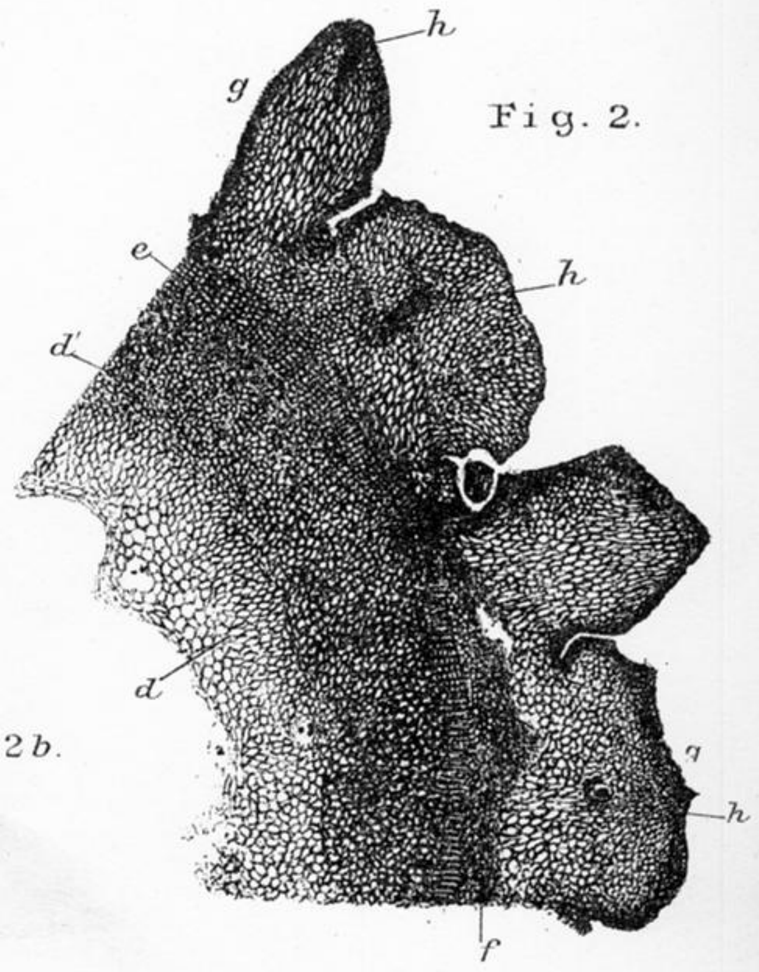
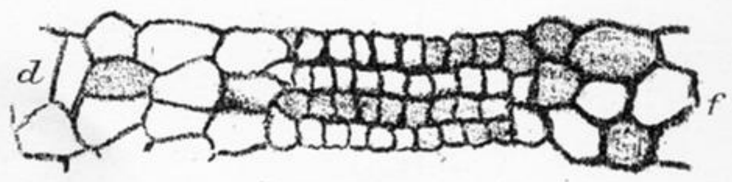


Fig. 2.

Fig. 4.



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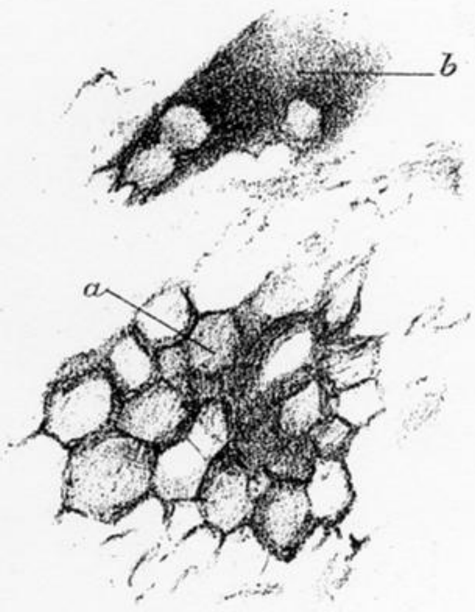
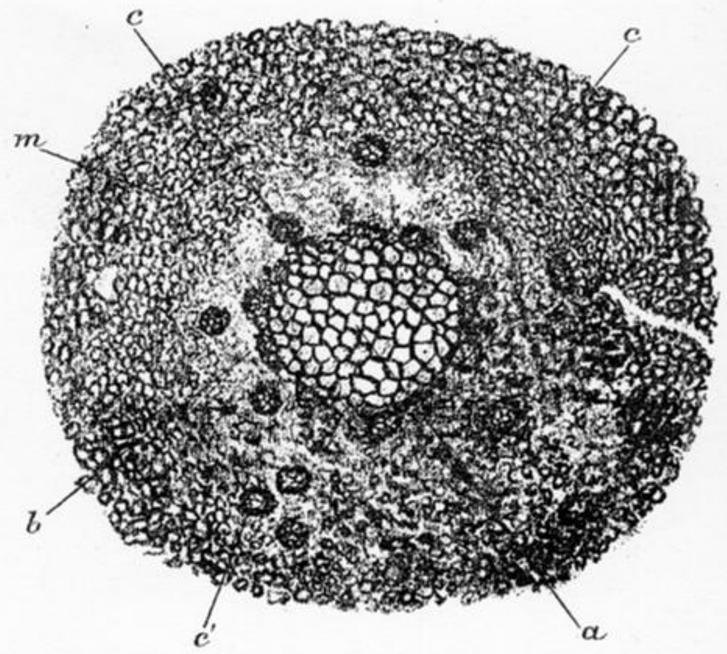


Fig. 28.



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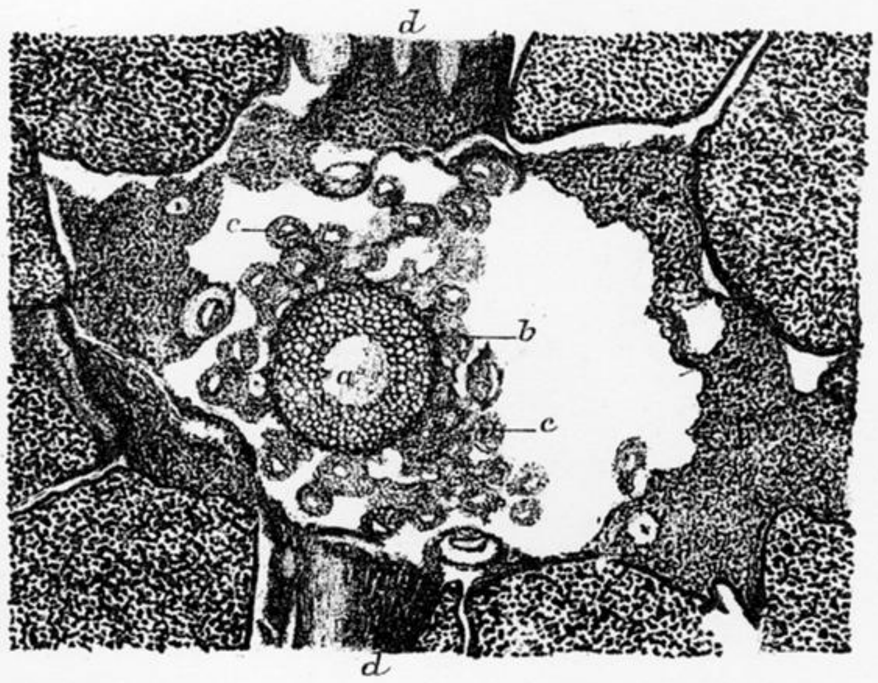
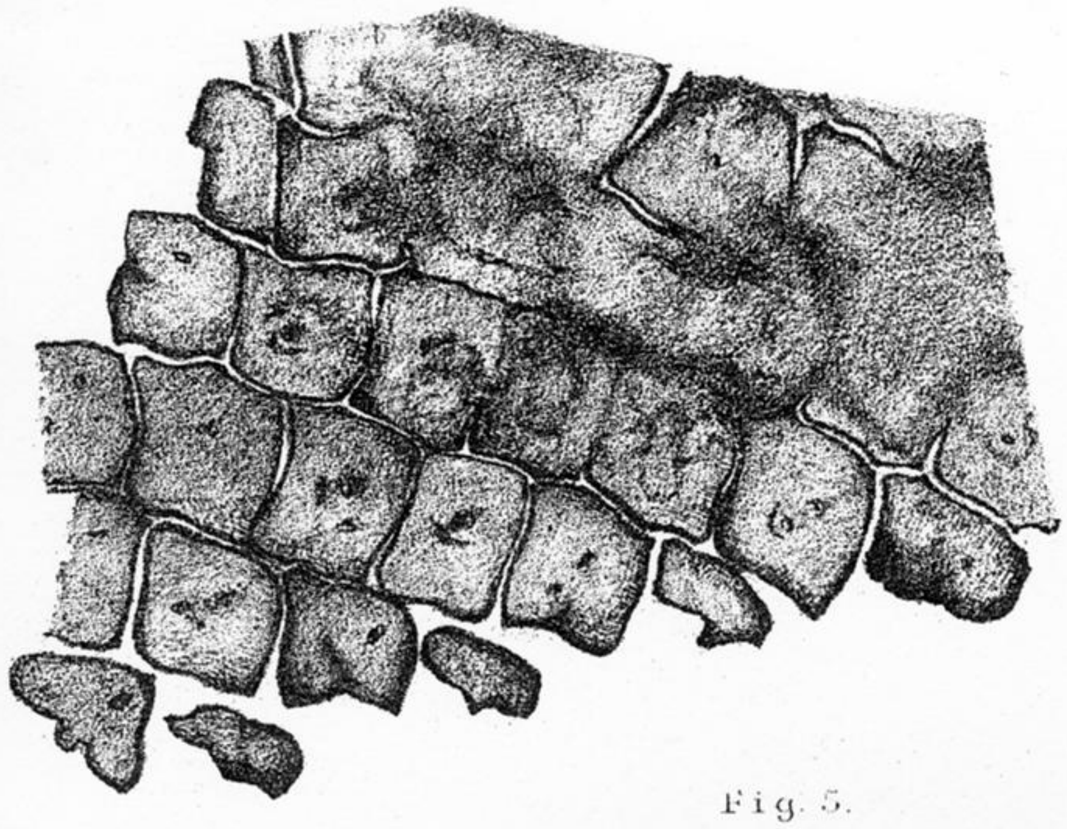


Fig. 14.



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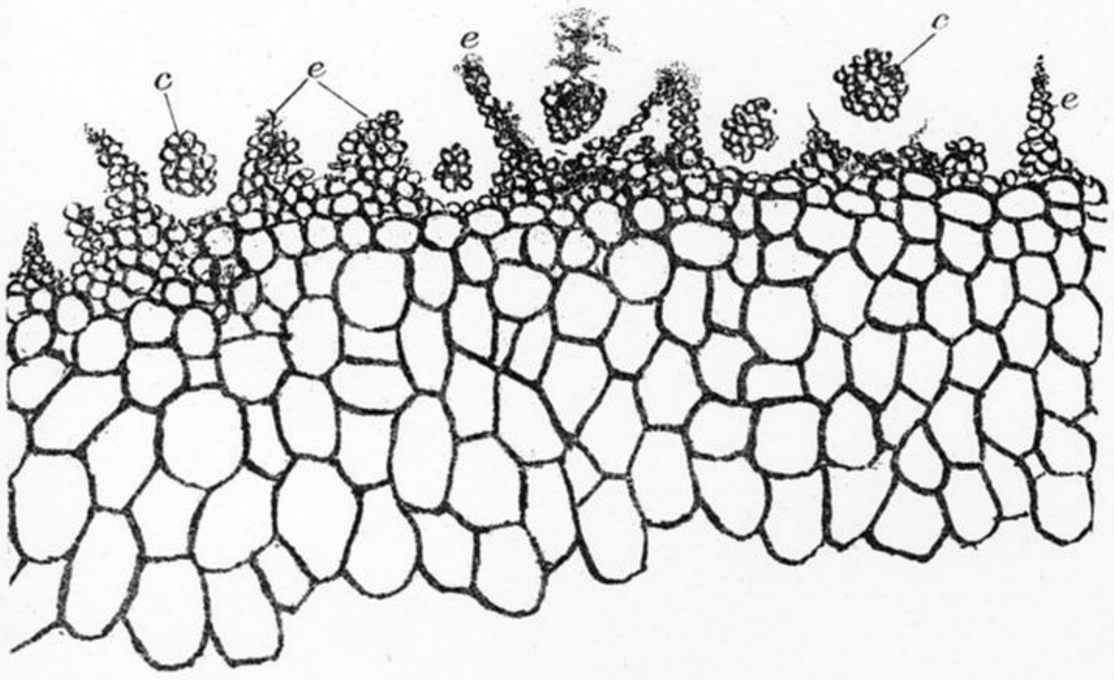

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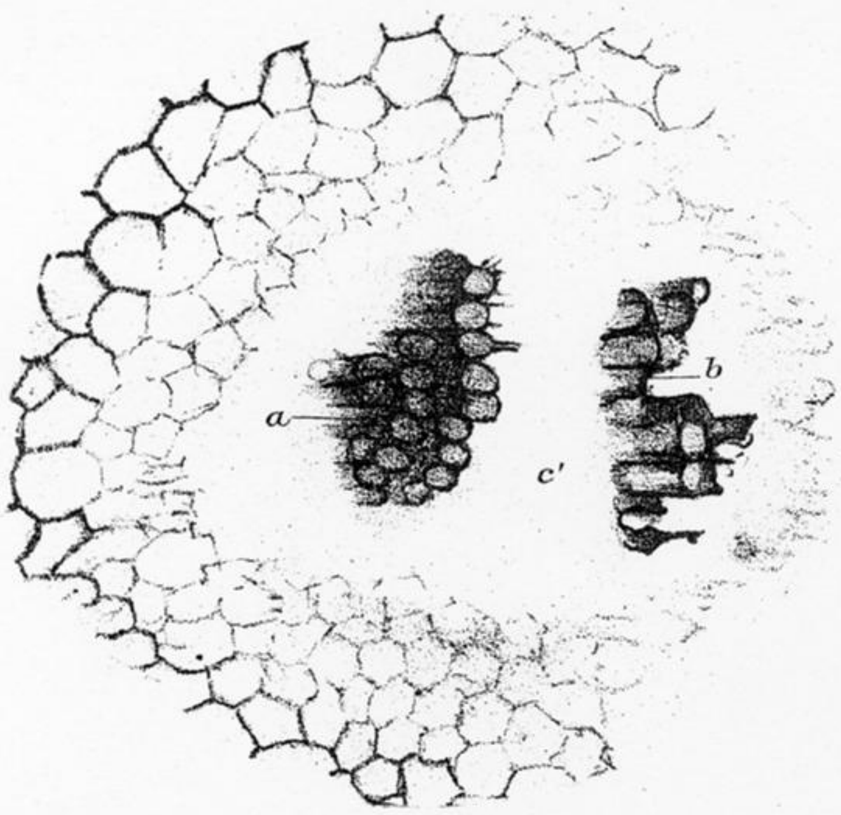


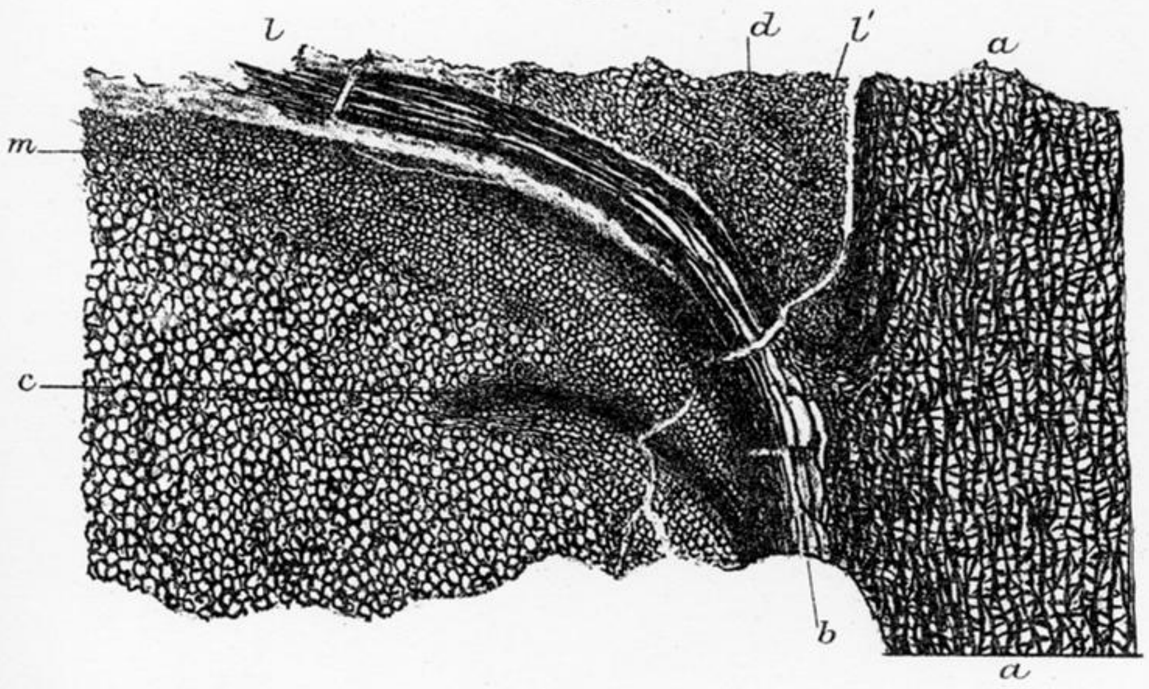


Fig. 25.

Fig. 10.

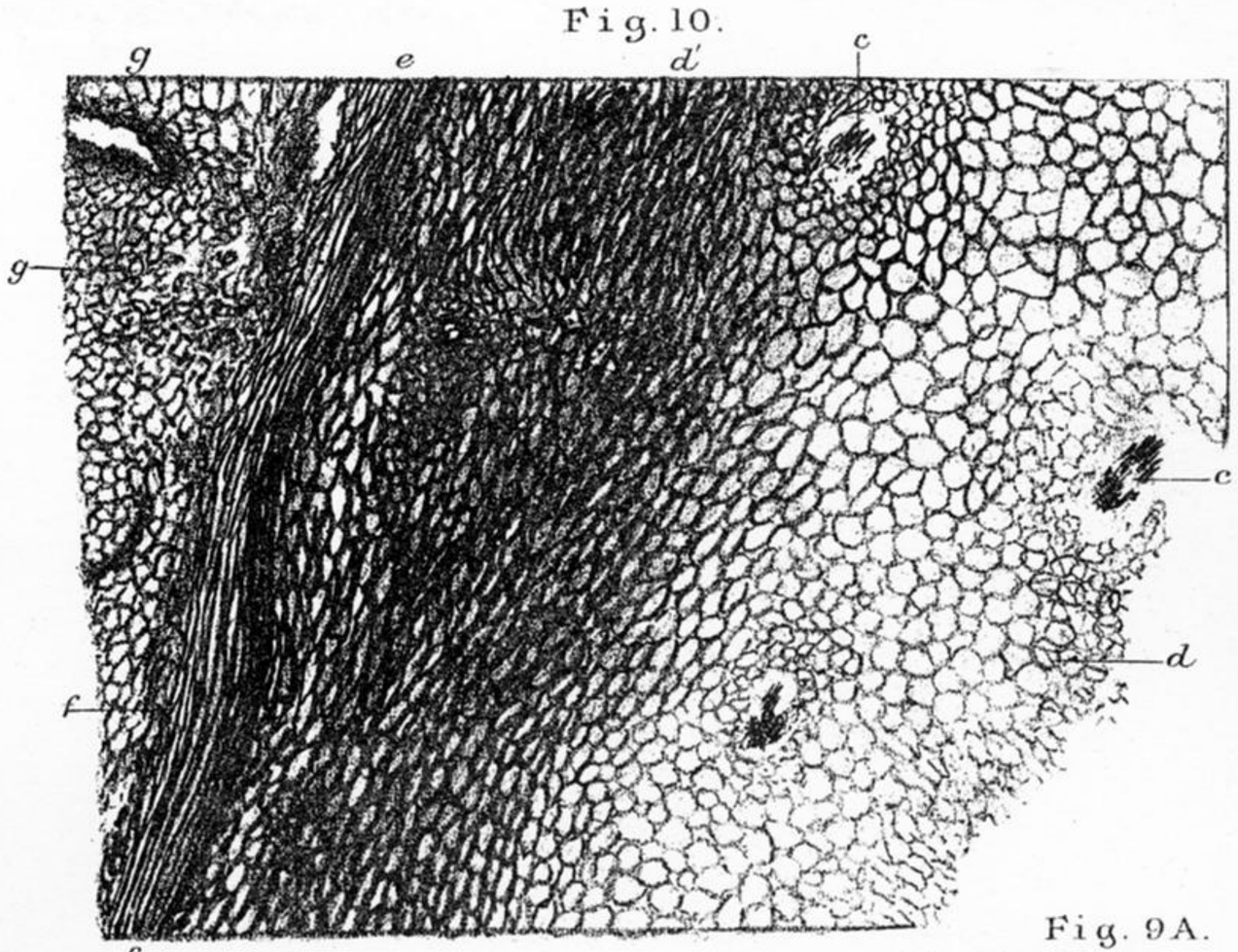
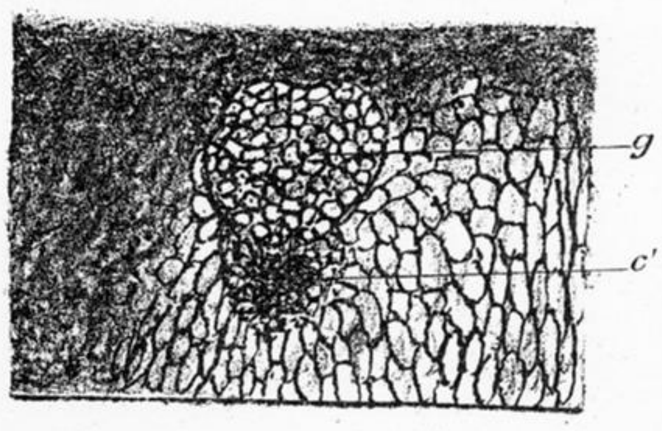
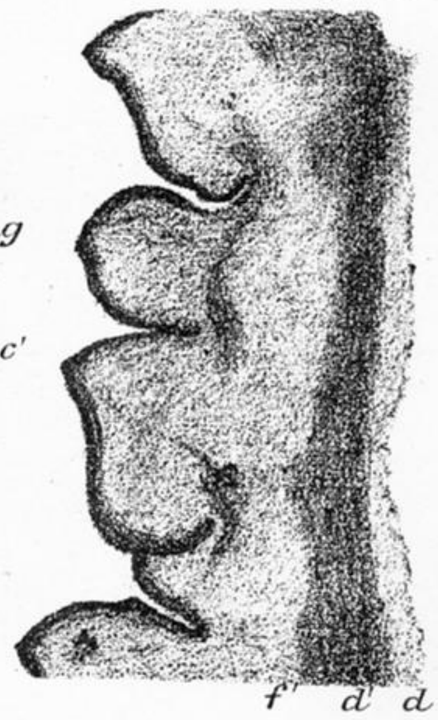
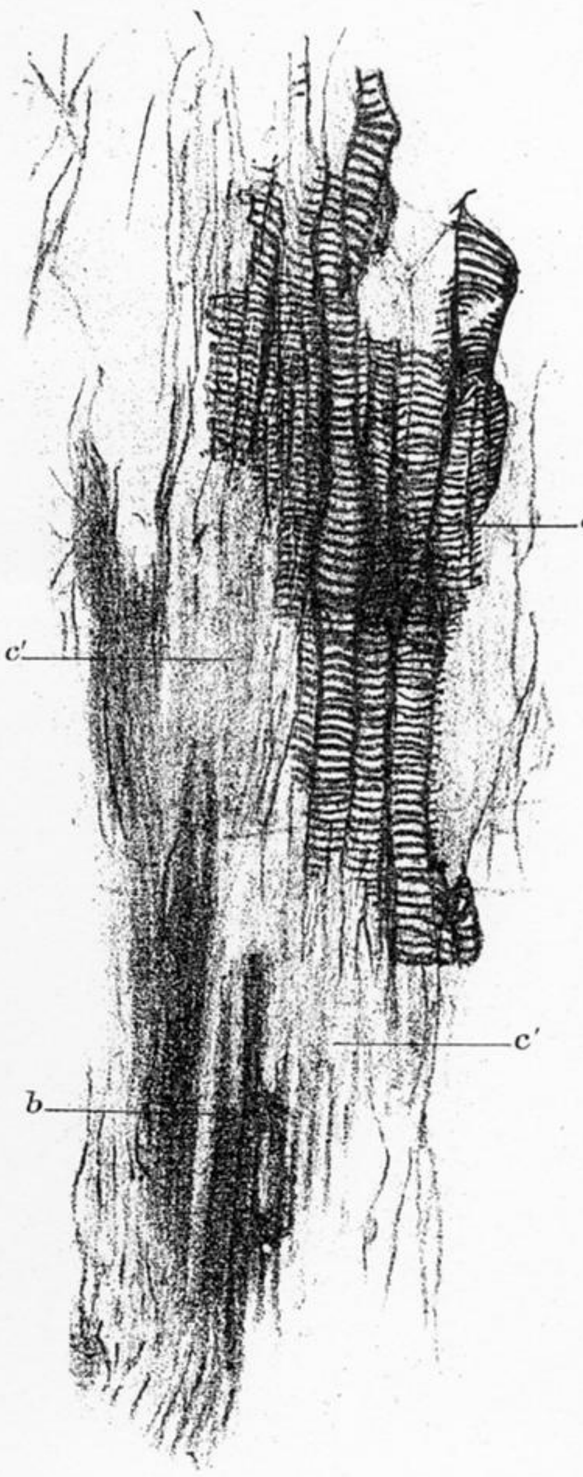


Fig. 9A.

Fig. 13.







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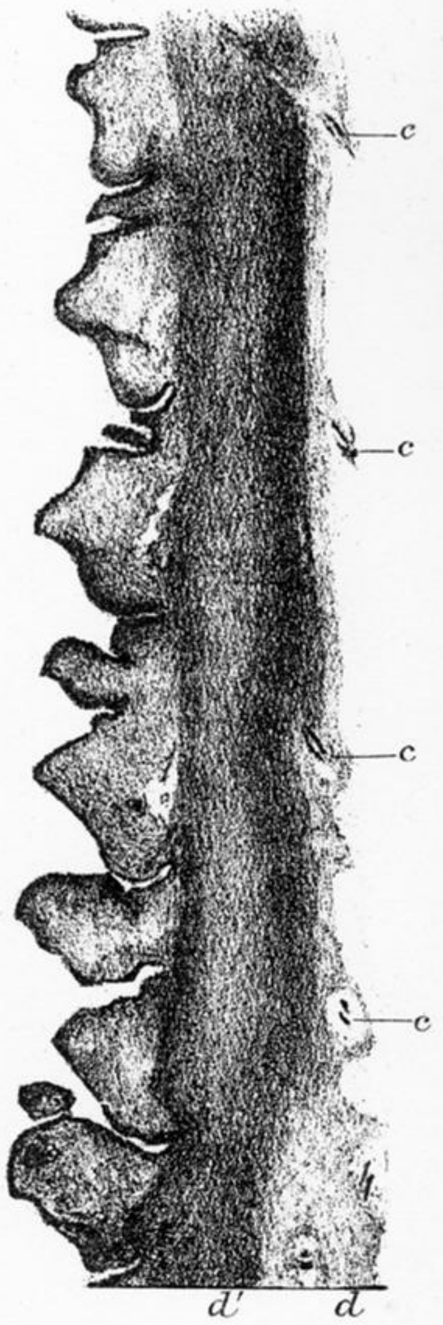
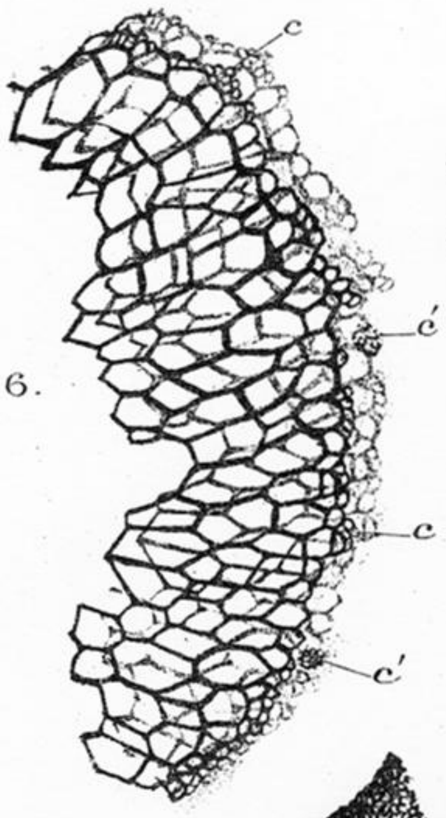


Fig. 9.

Fig. 6.



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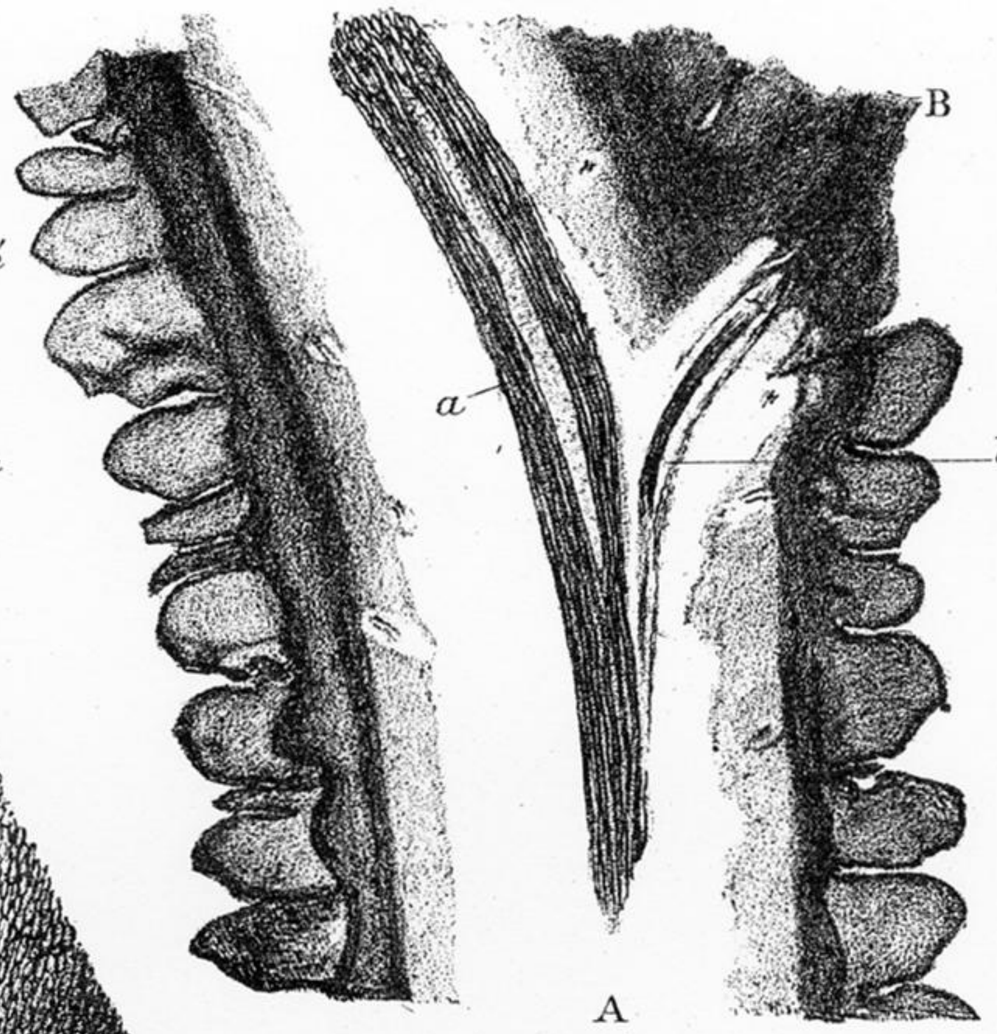

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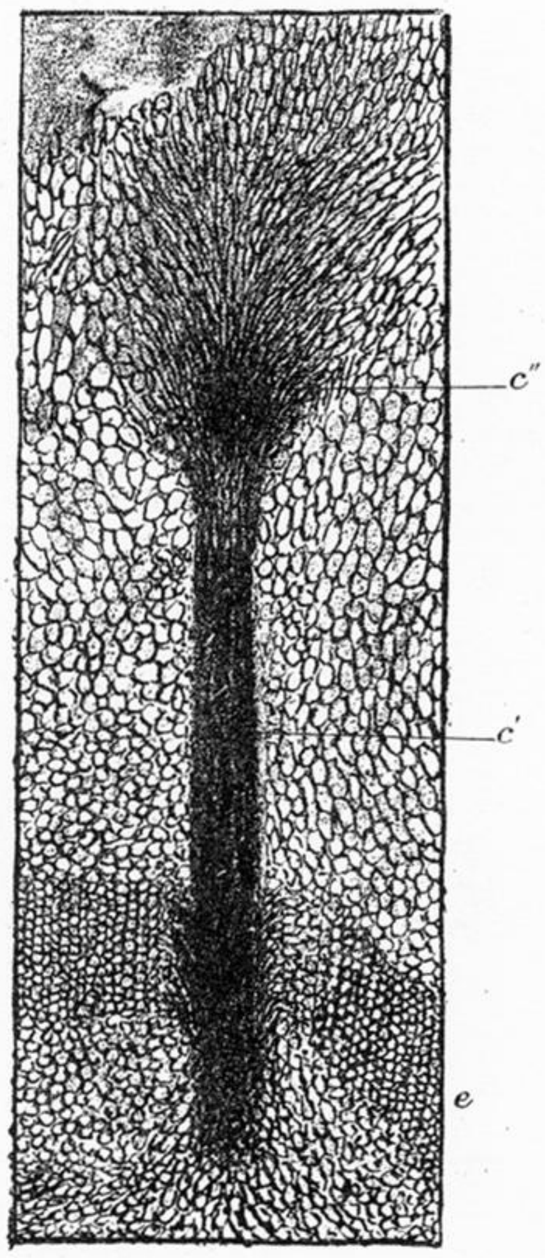

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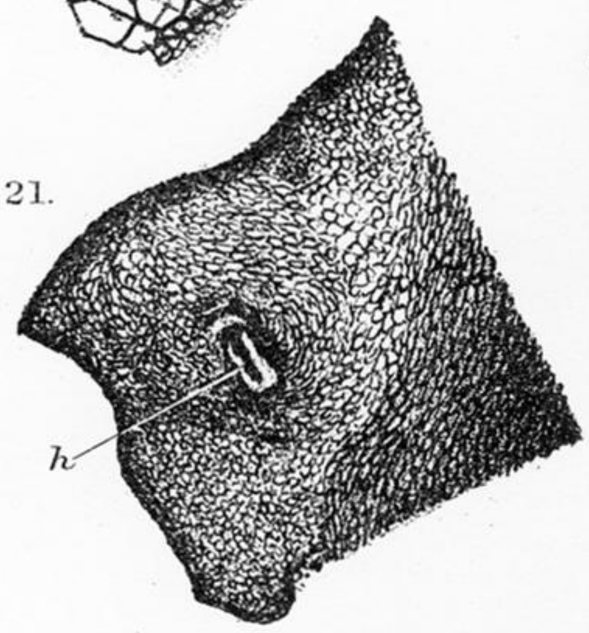

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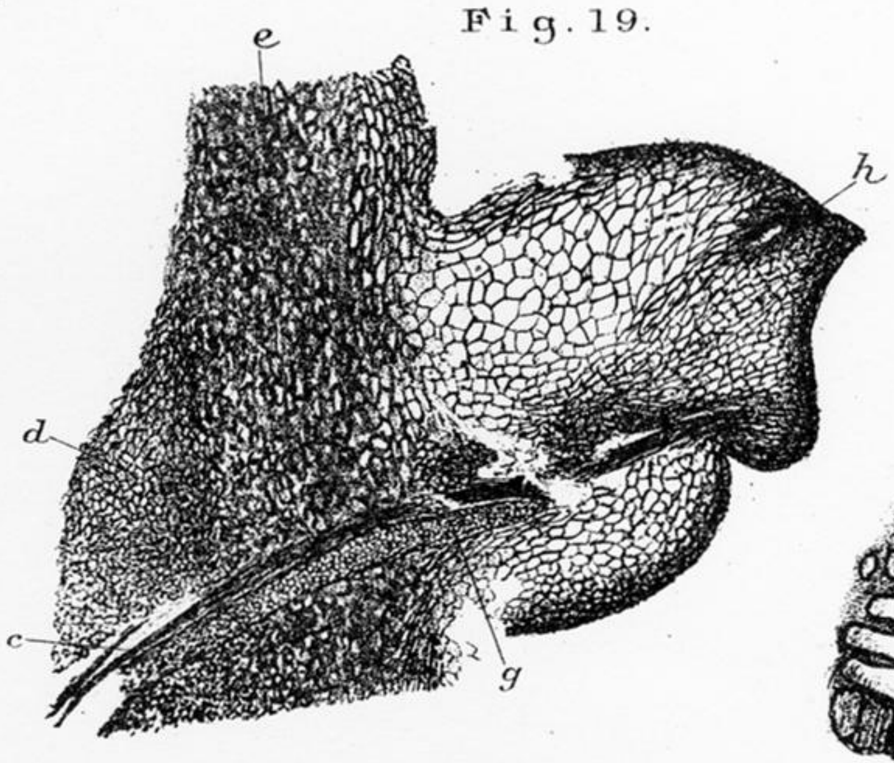


Fig. 30A.

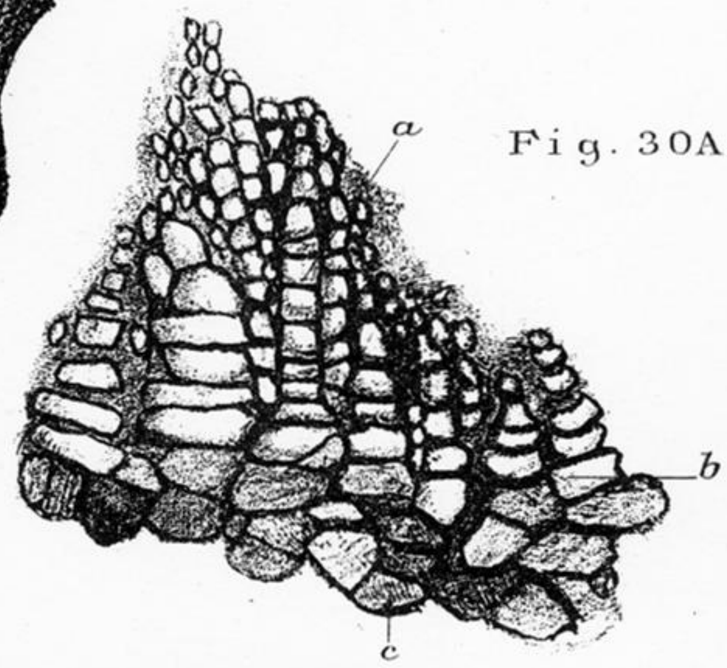
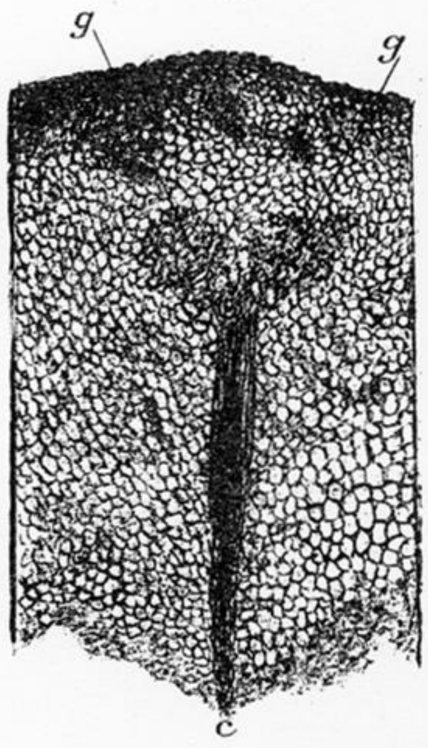


Fig. 17.



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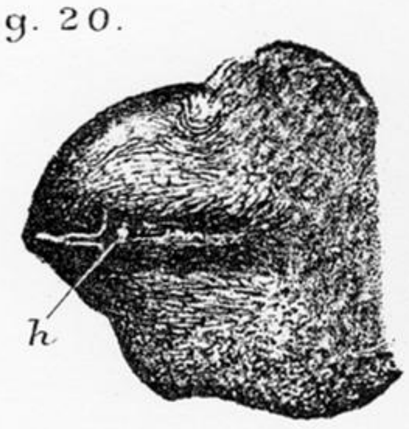


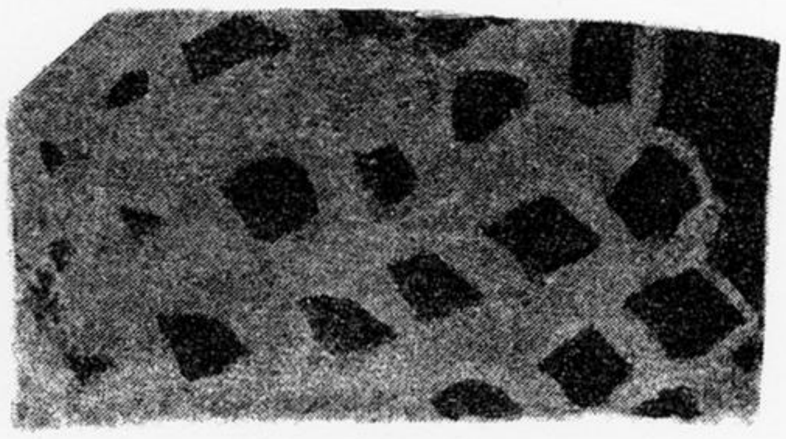
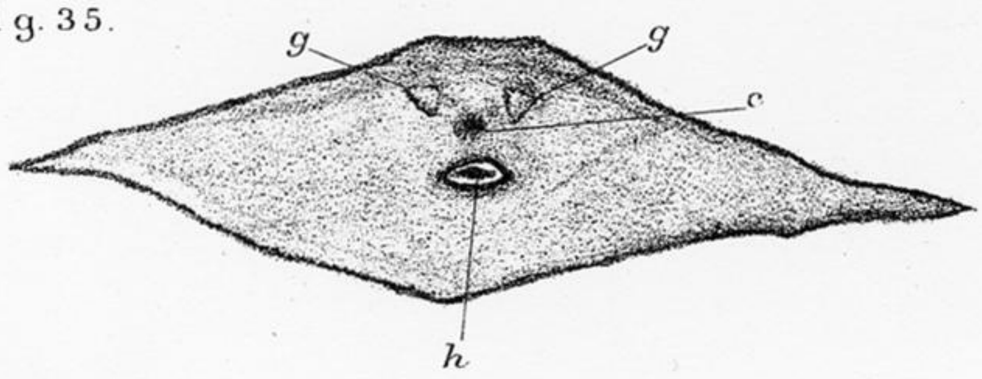


Fig. 15.

Fig. 35.



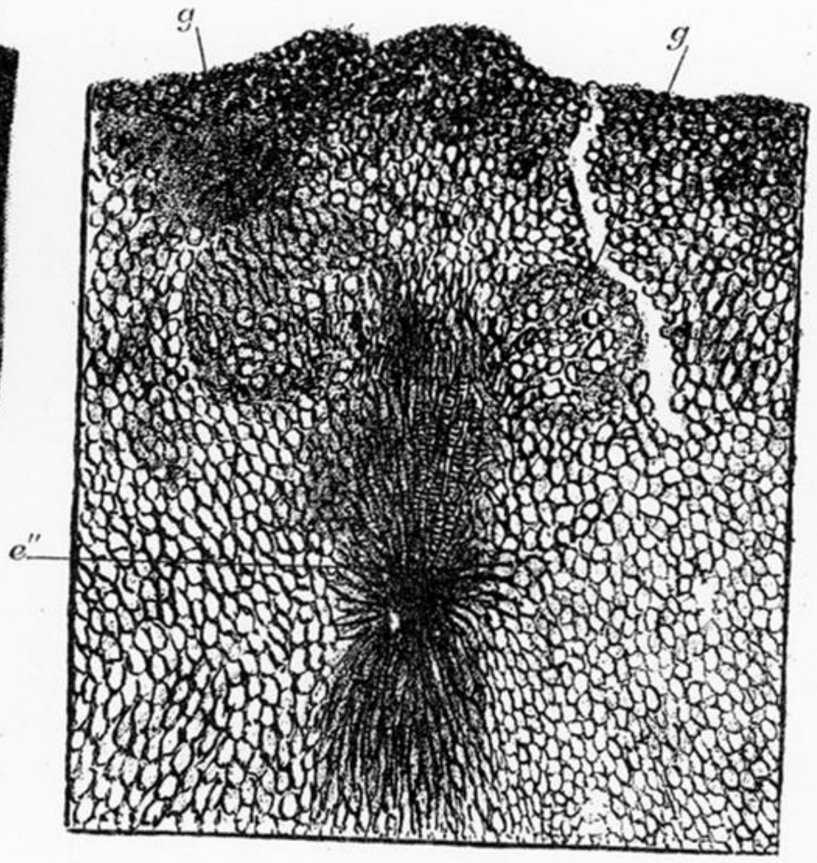


Fig. 18.

Fig. 31.

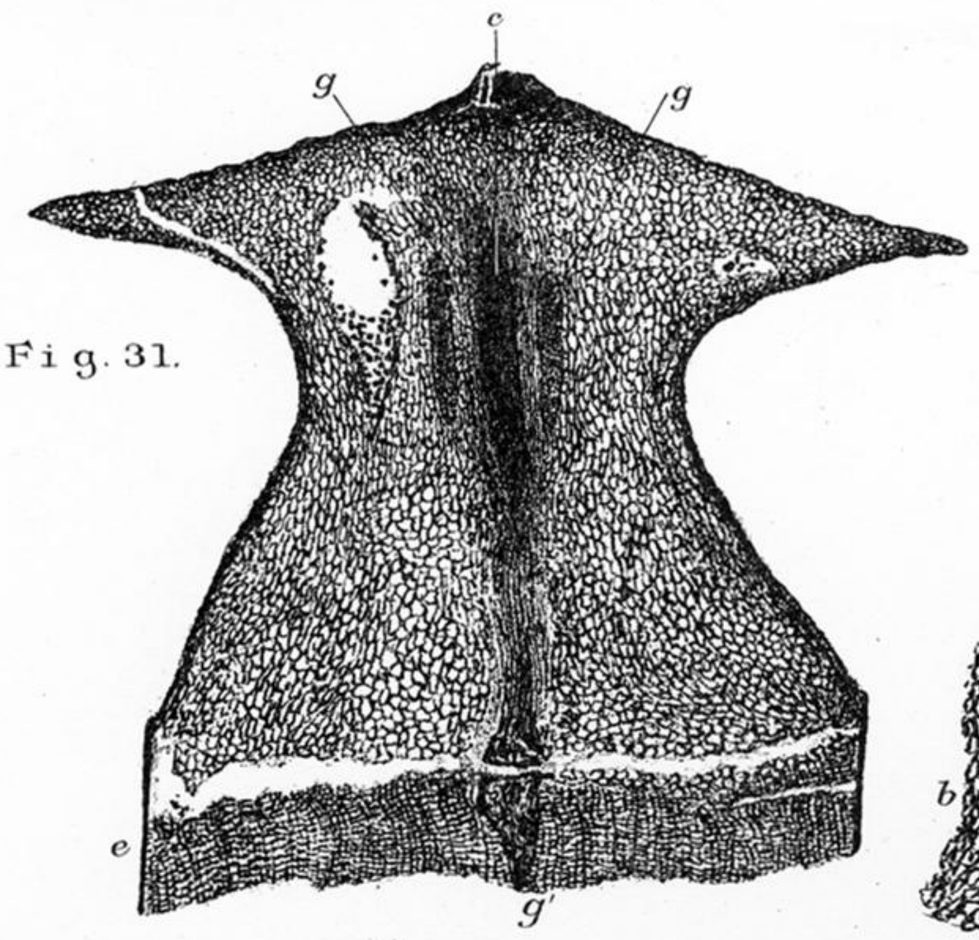
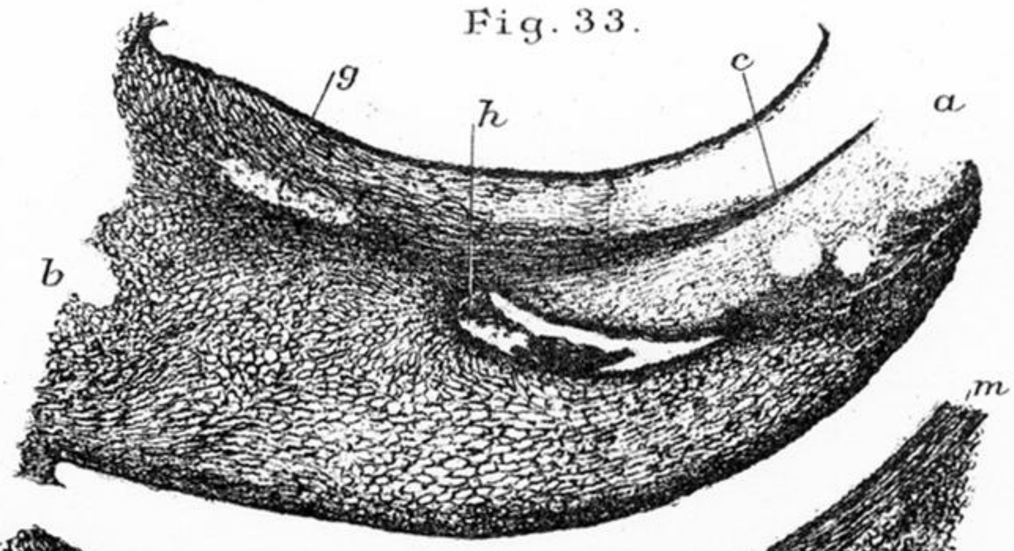


Fig. 33.



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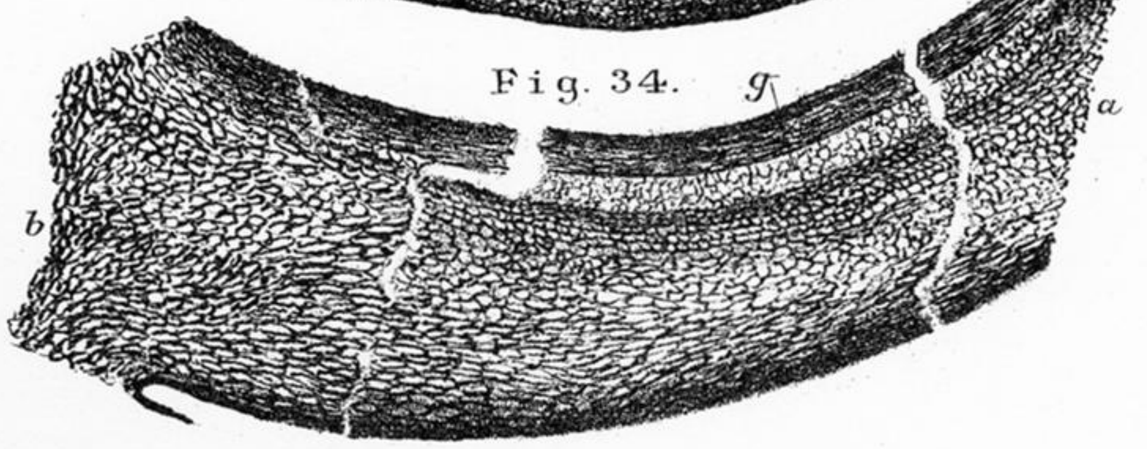


Fig. 30.

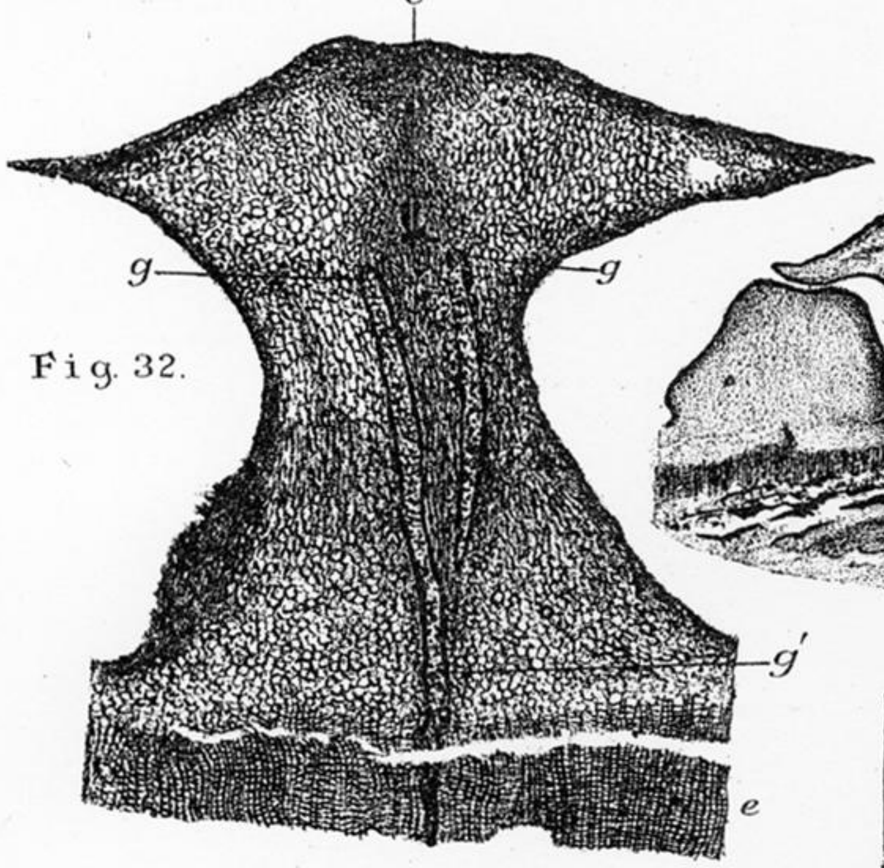


Fig. 32.

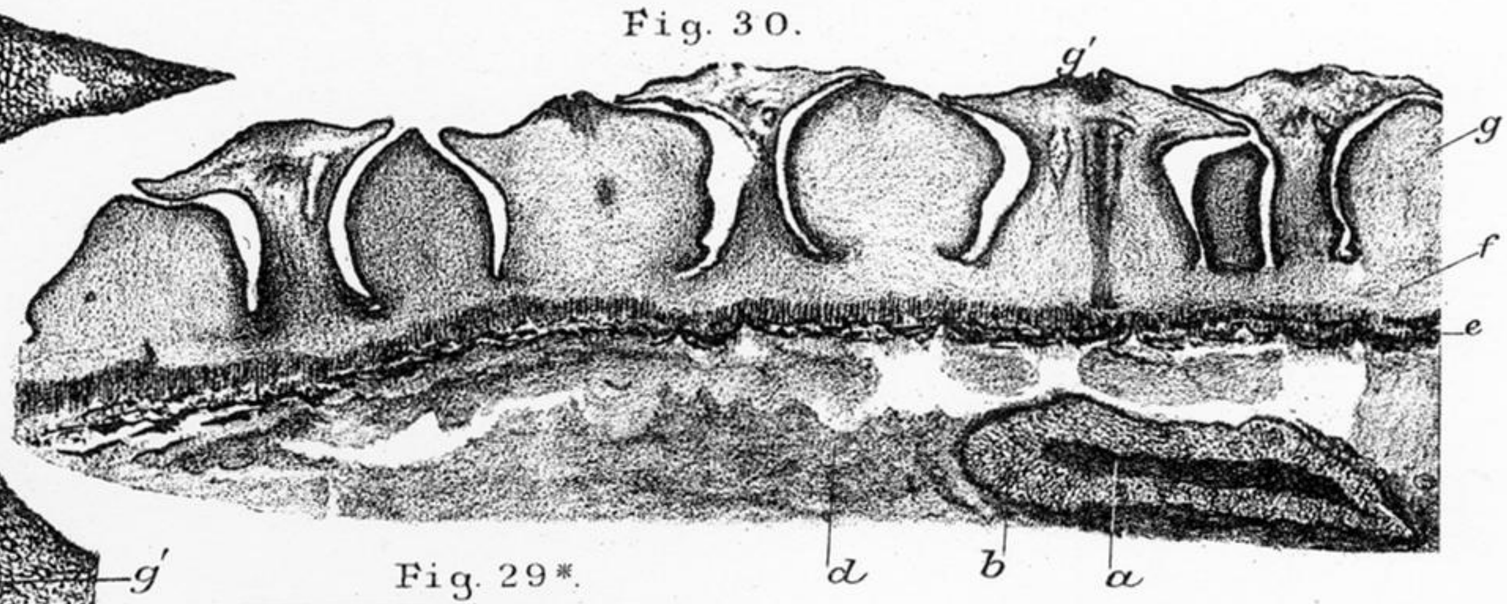
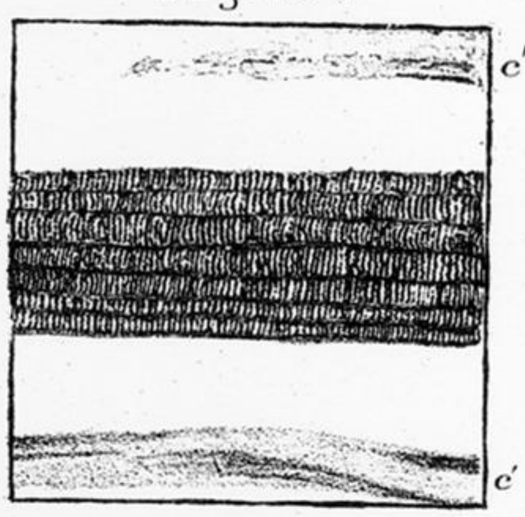


Fig. 29*.



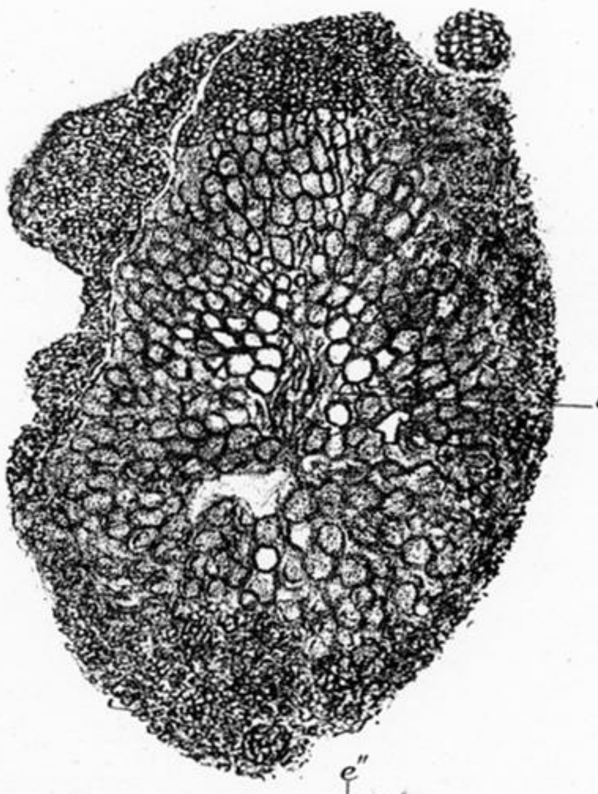


Fig. 39.

Fig. 36.

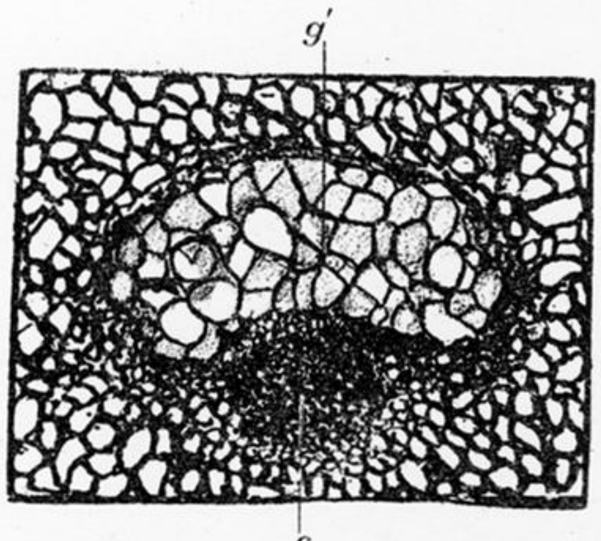
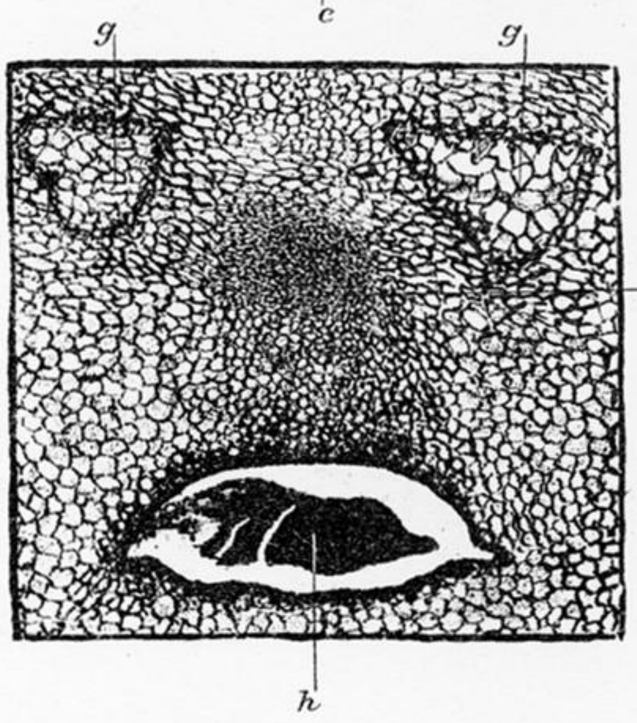


Fig. 37.



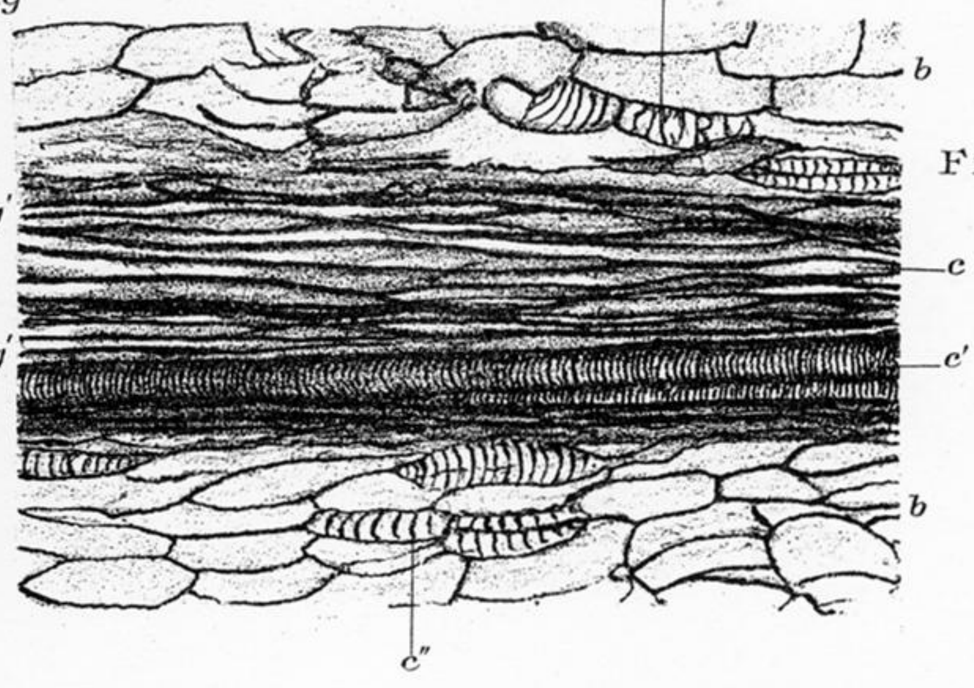


Fig. 38.

Fig. 35.

Fig.23.

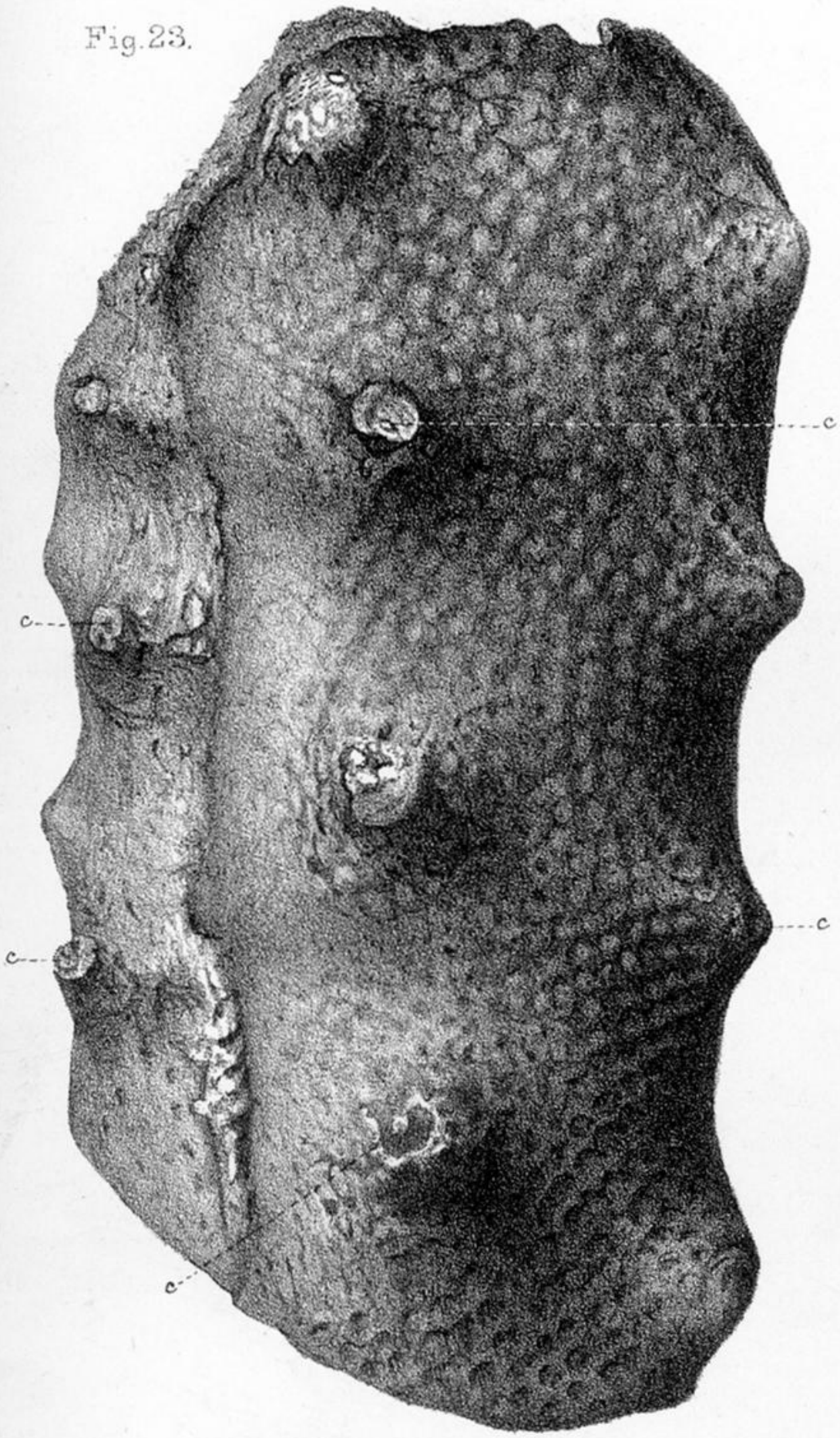


Fig.27.A.

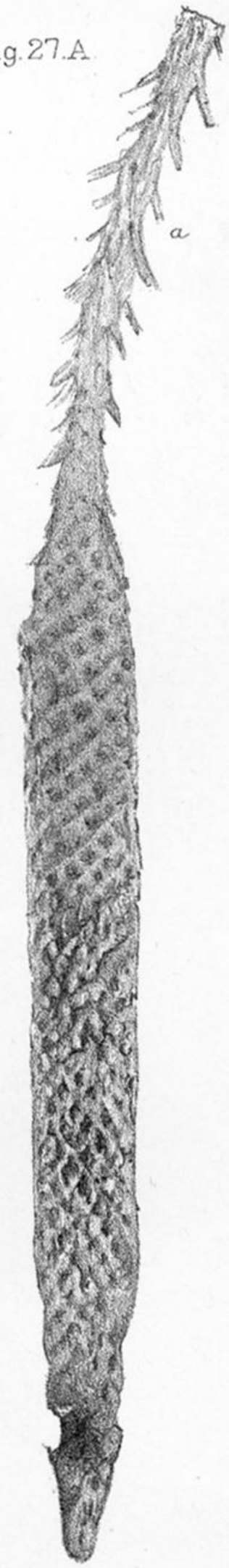


Fig.24.

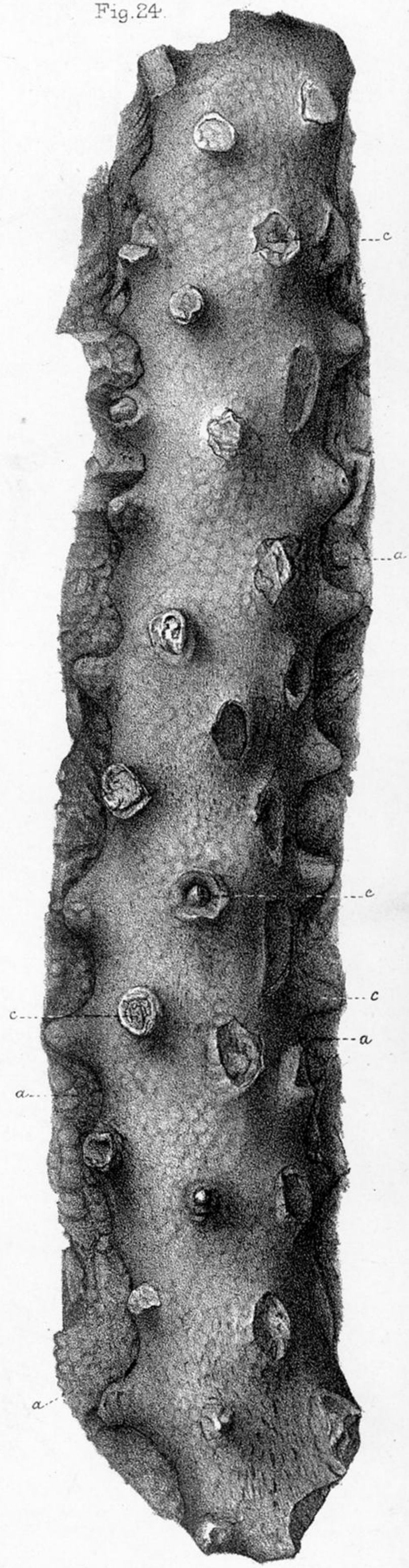


Fig.7.

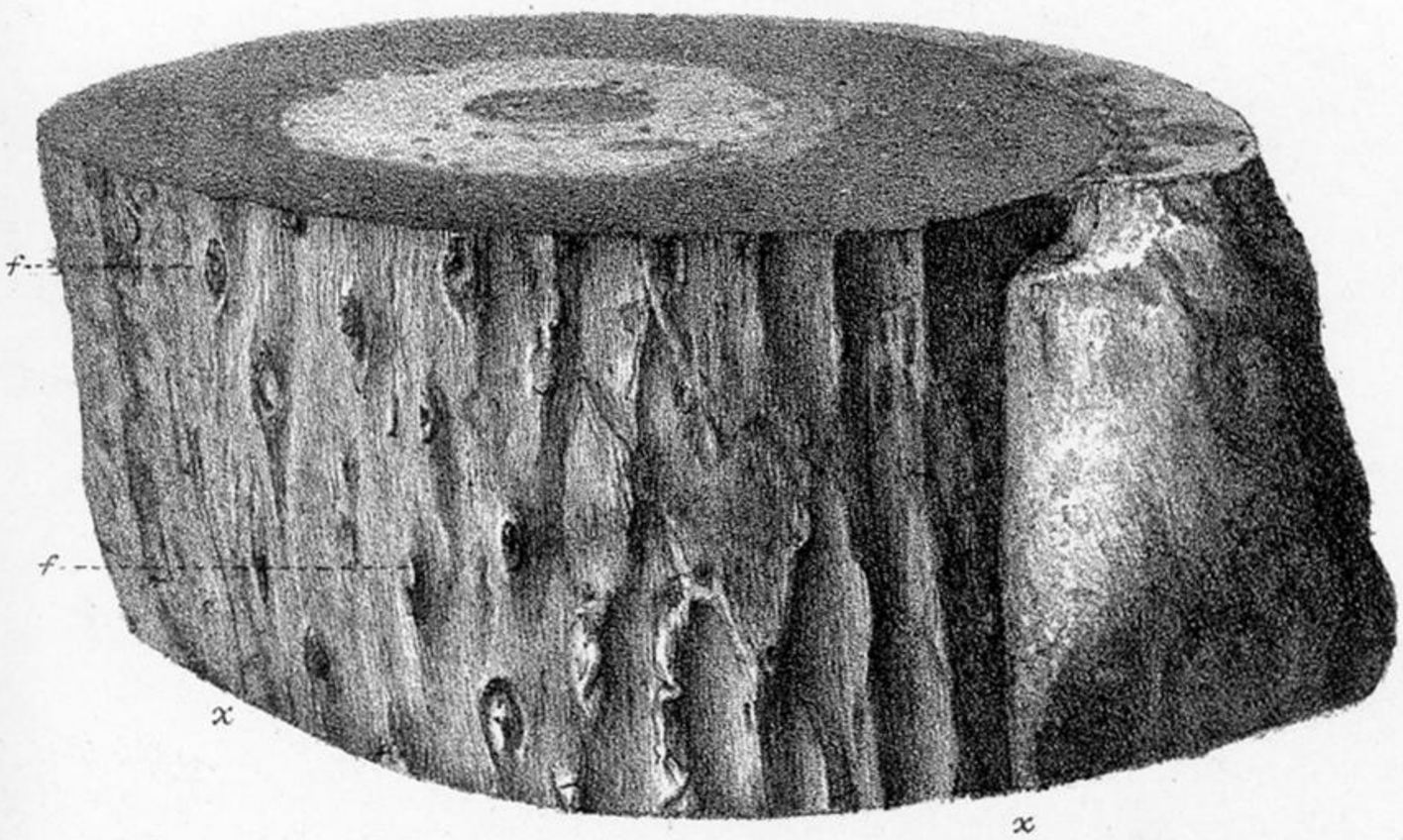


Fig.61.

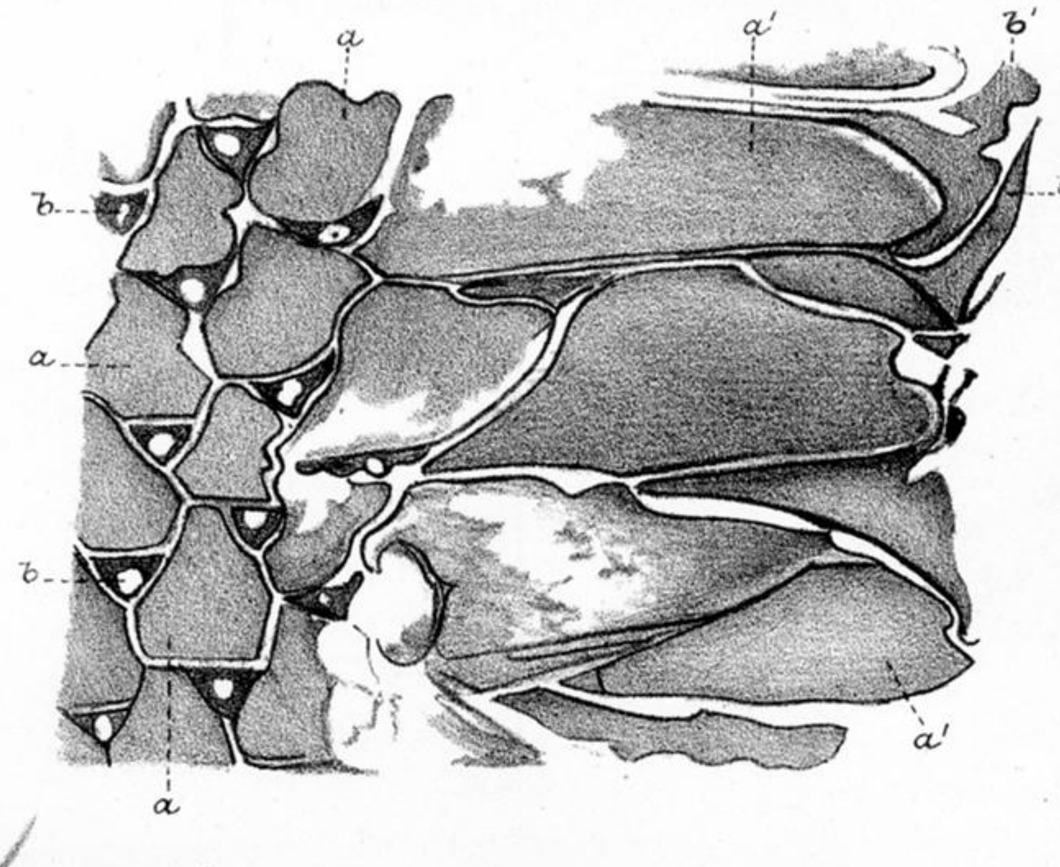


Fig.22.

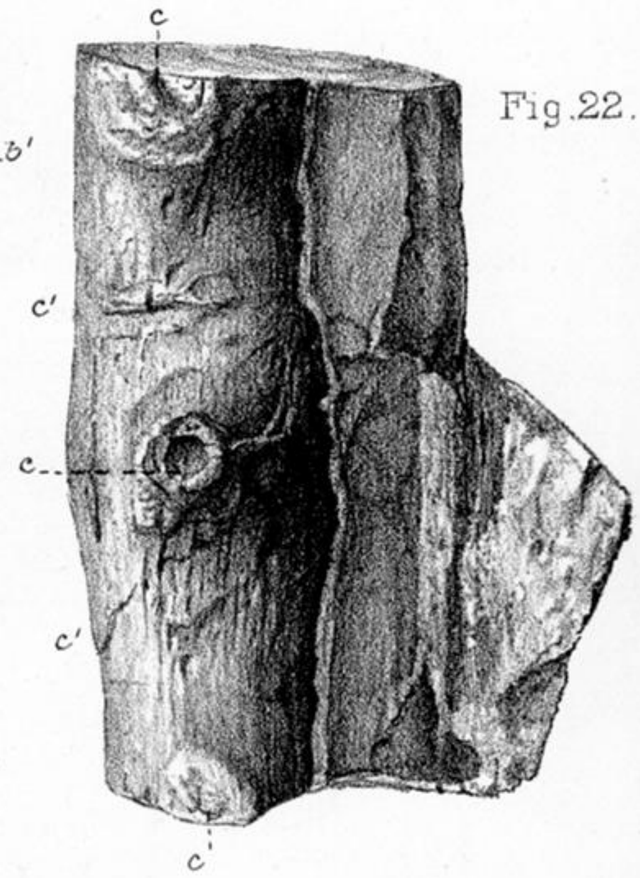
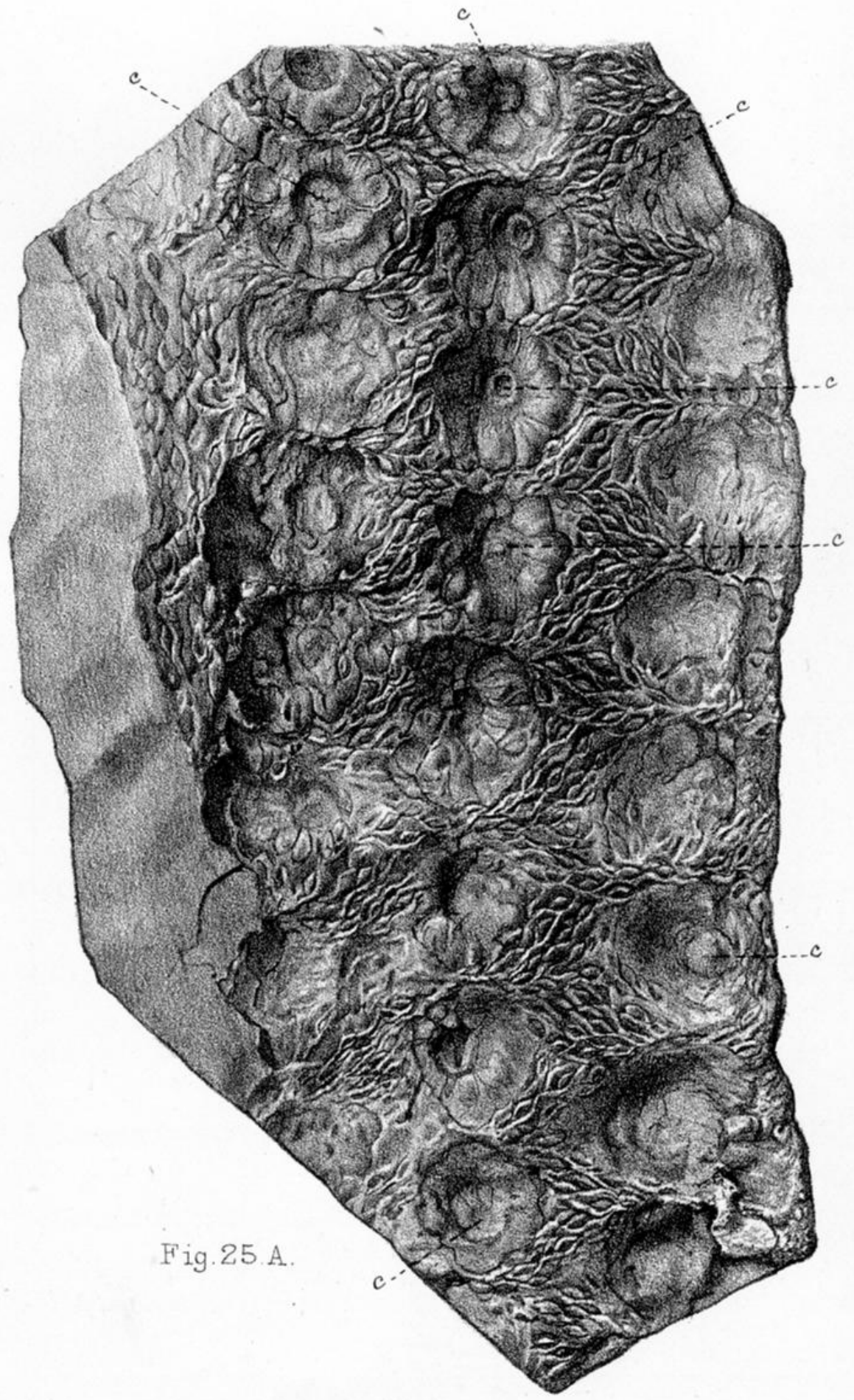


Fig.26.A.



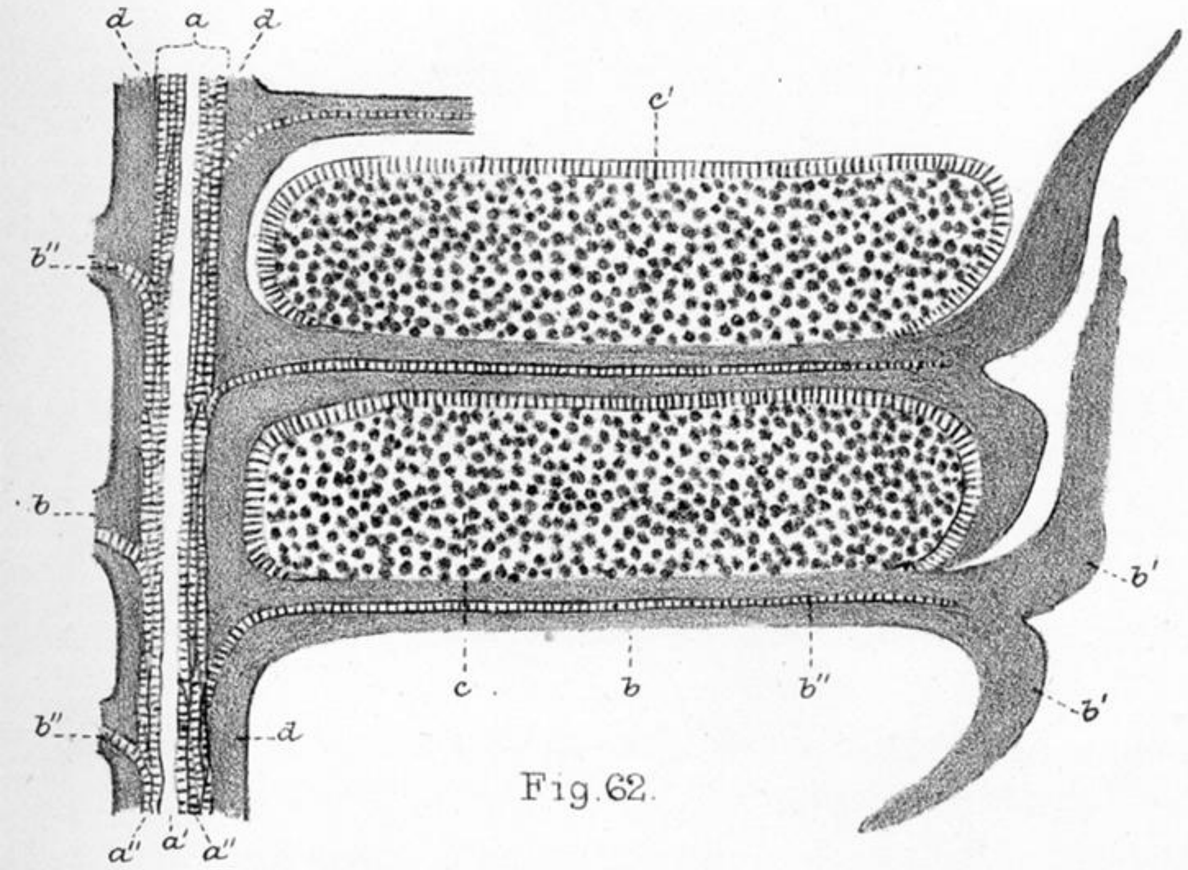
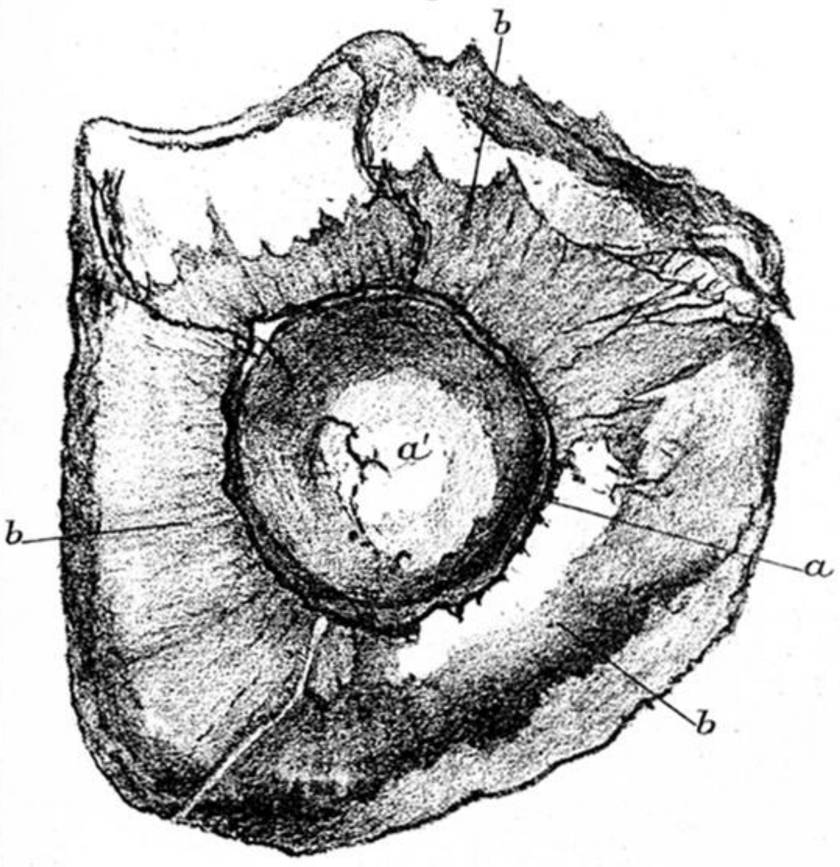


Fig.62.

Fig.25.A.

Fig. 43.



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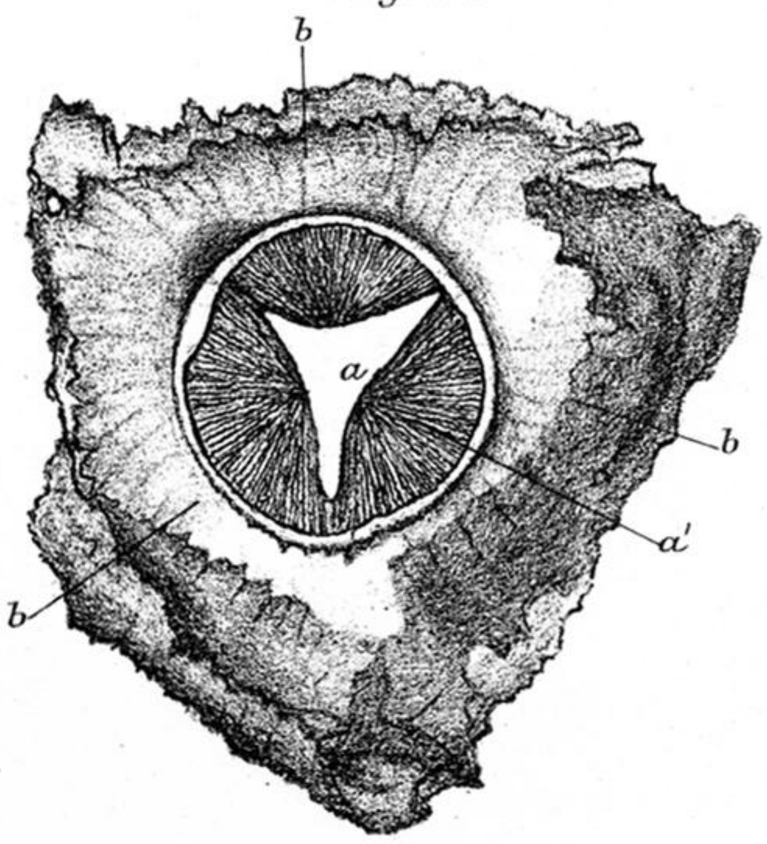
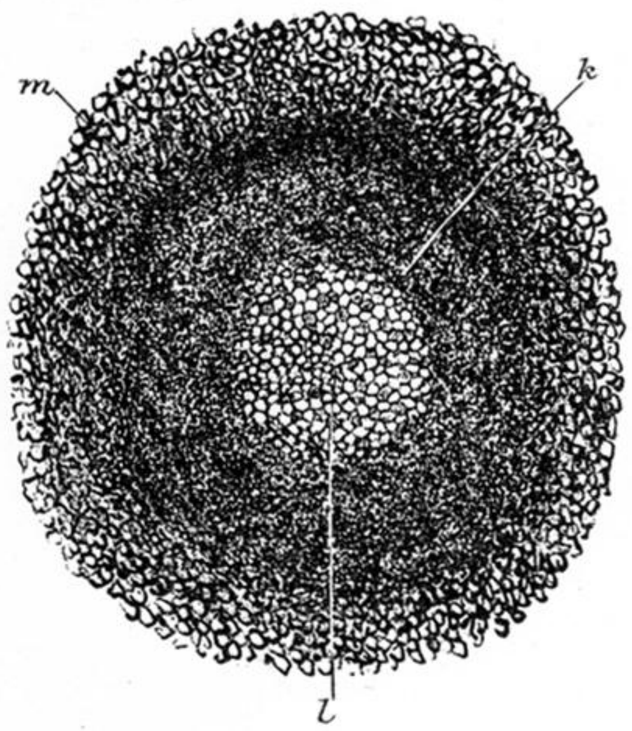


Fig. 40A.

Fig. 40.



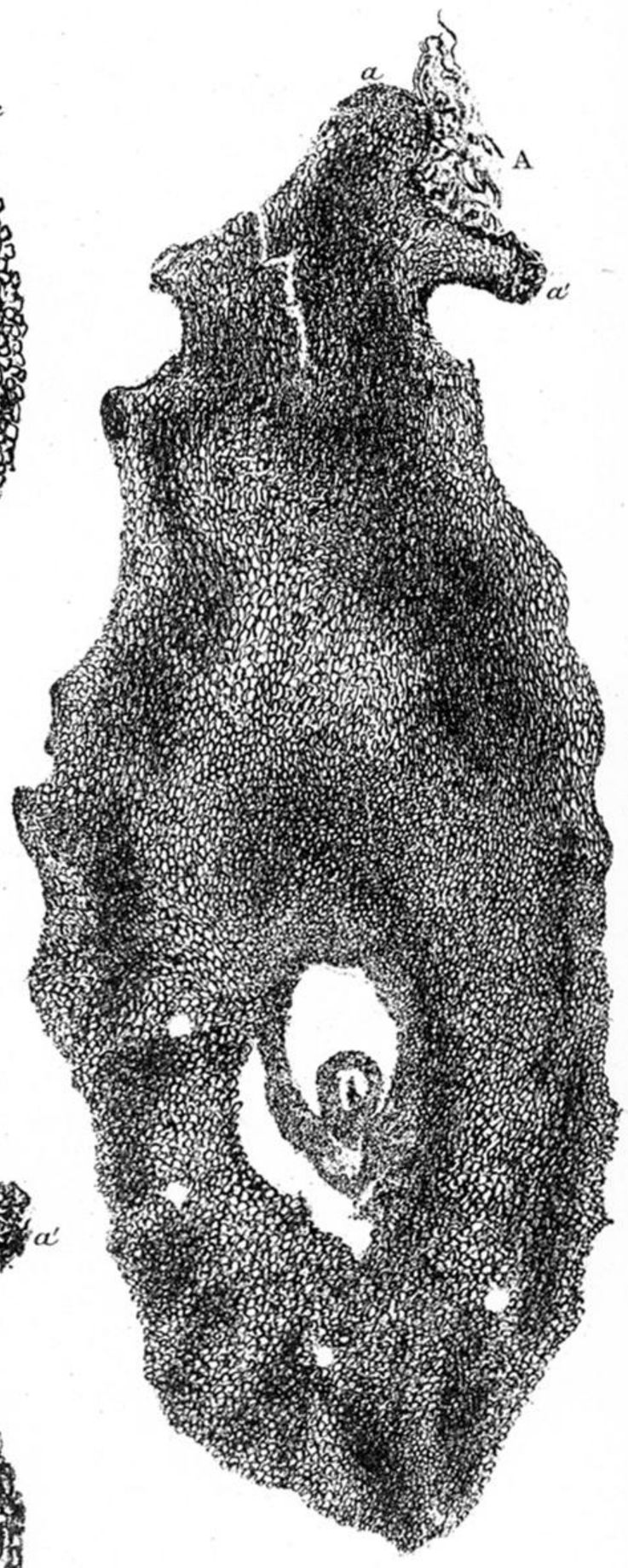


Fig. 42.

Fig. 50.

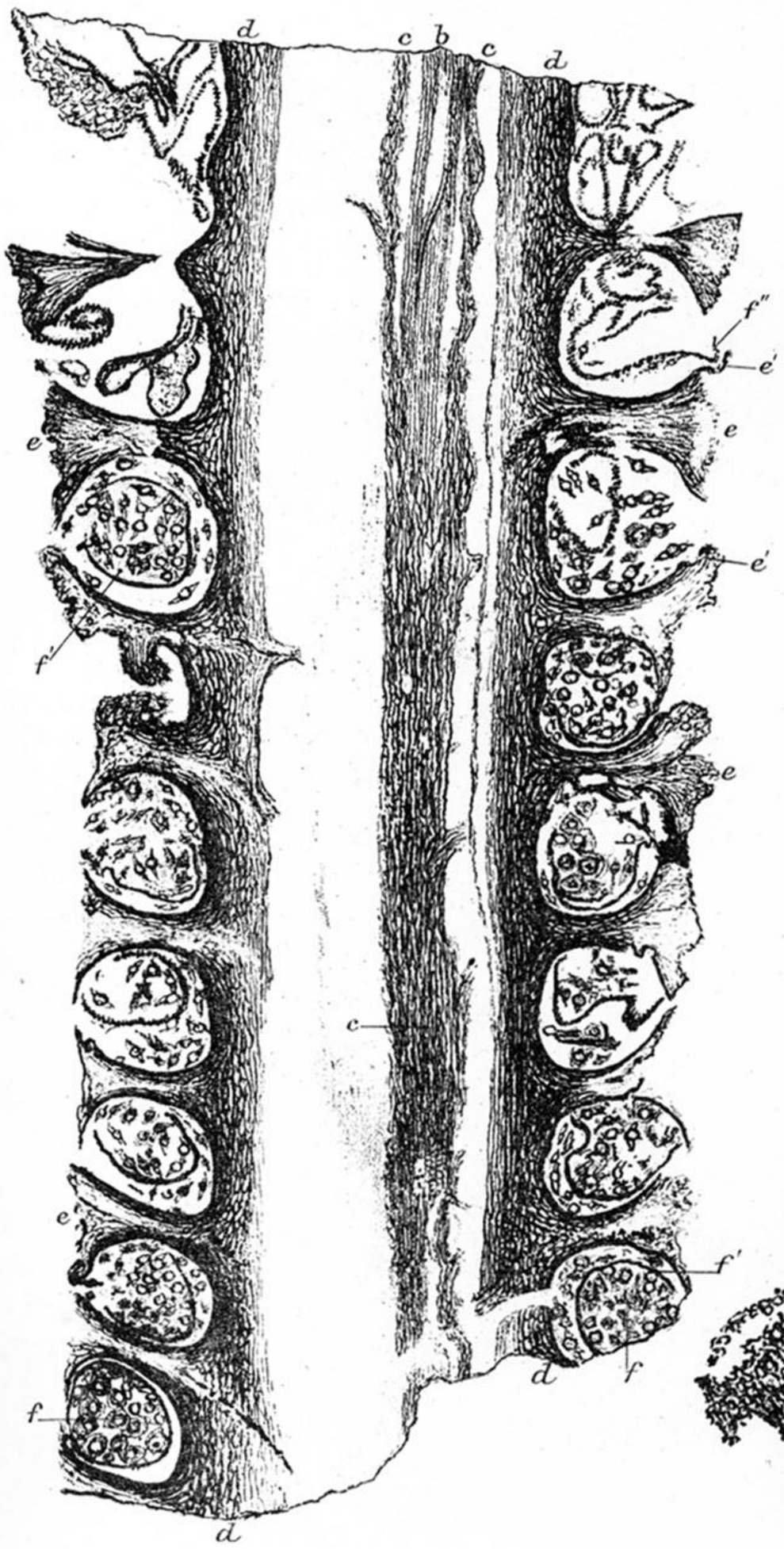


Fig. 41.

Fig. 52.

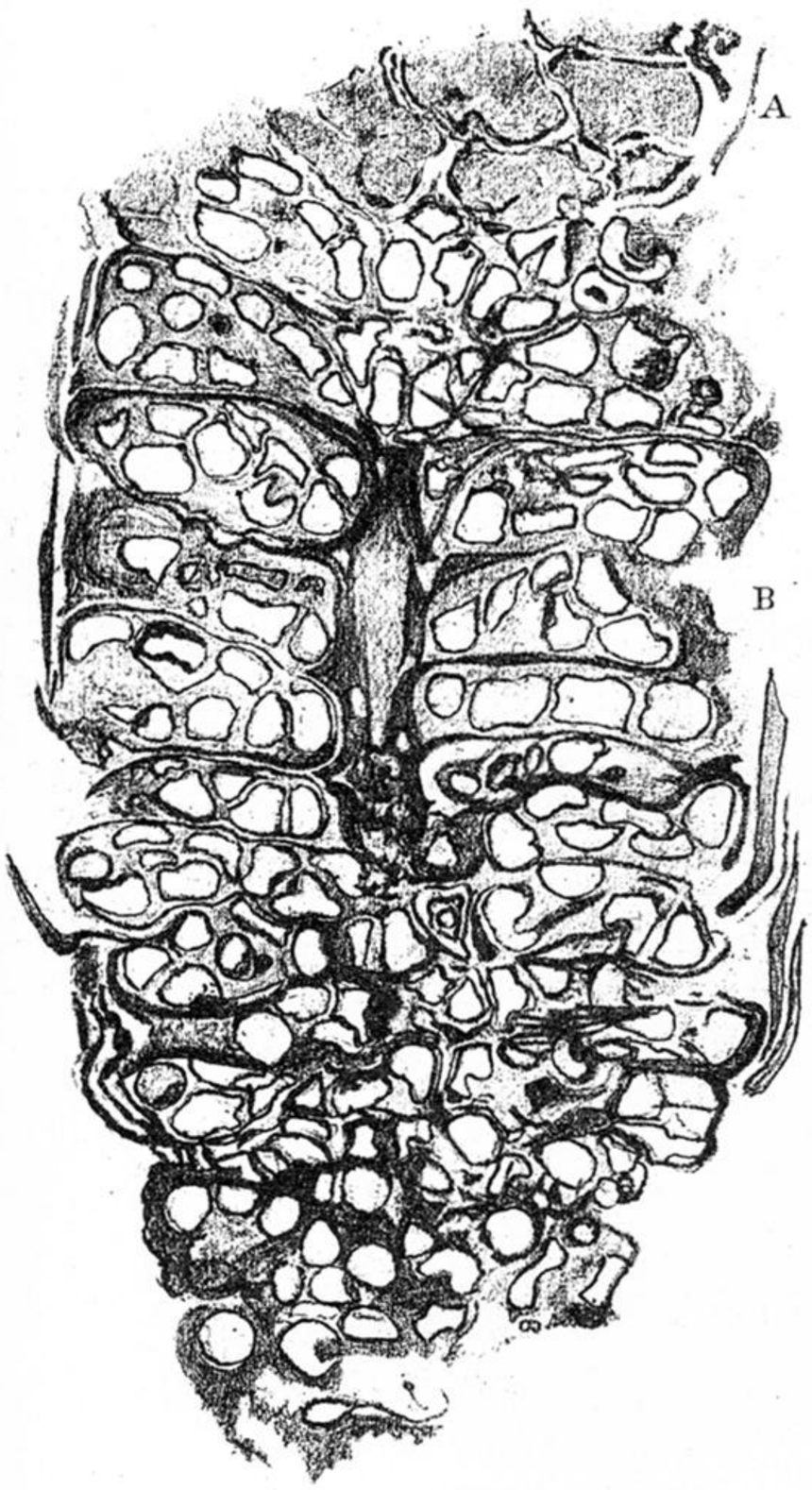
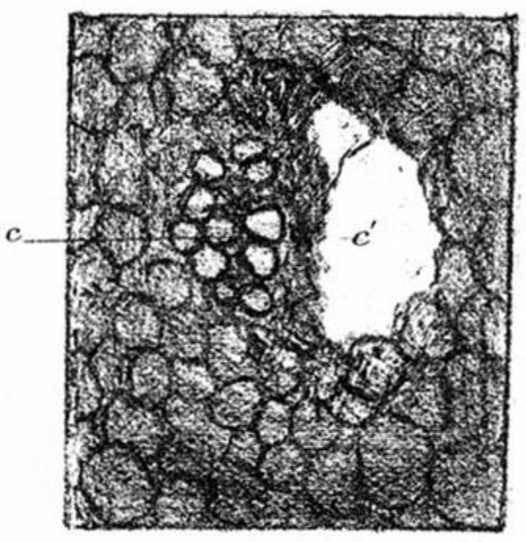


Fig. 55.

Fig. 60.



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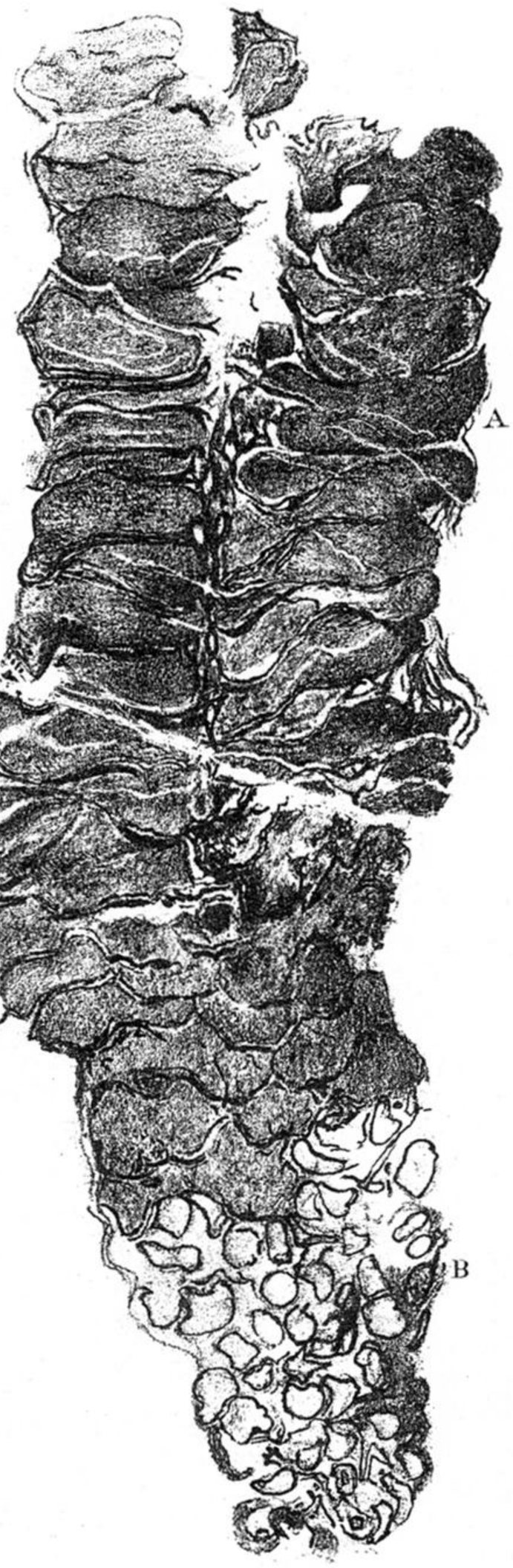
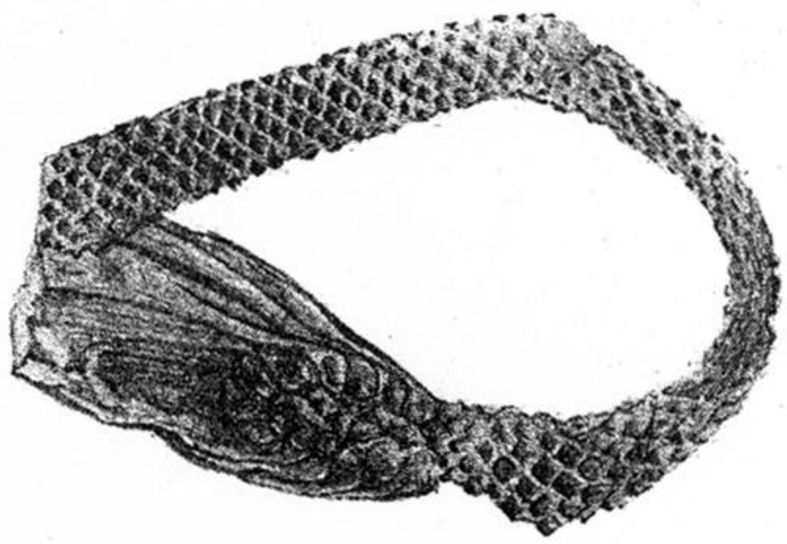
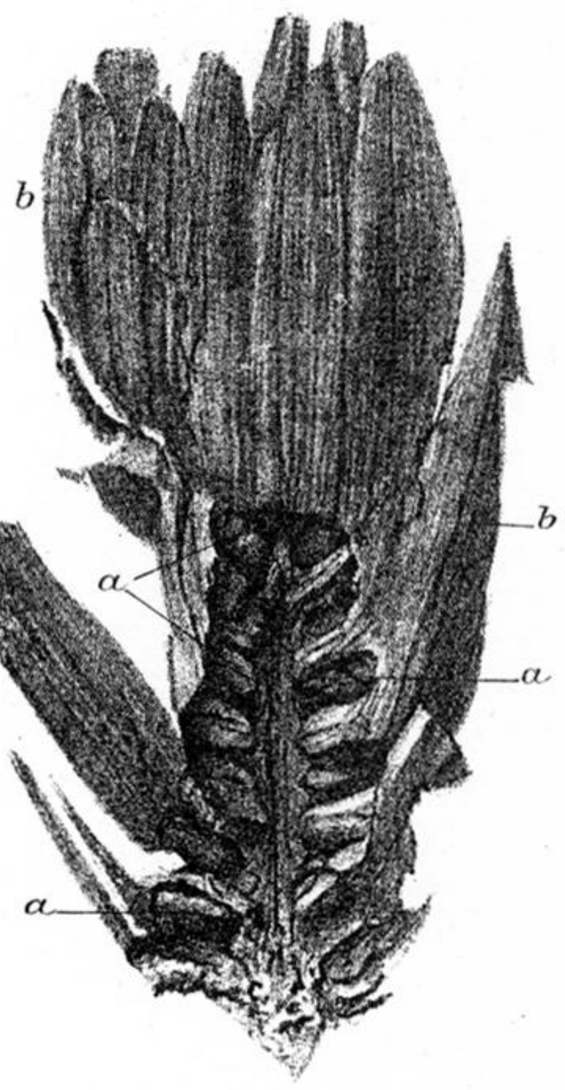


Fig. 54.





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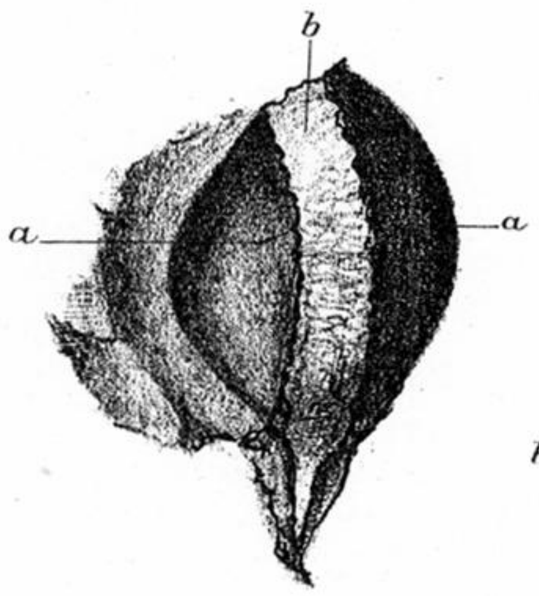

Fig. 45.

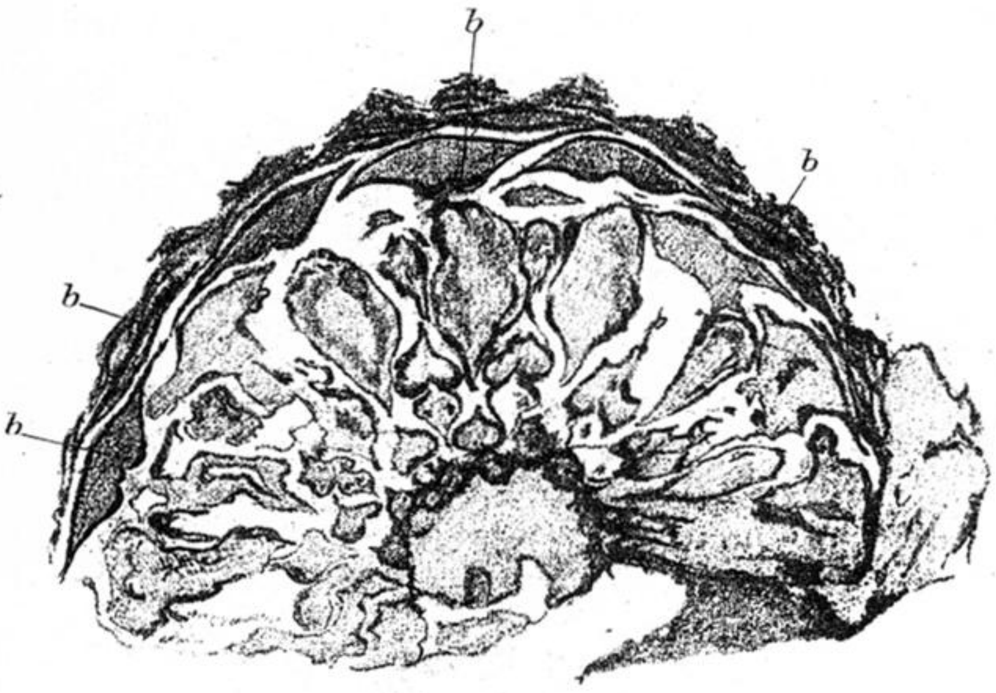

Fig. 56.

Fig. 64.

Fig. 63.

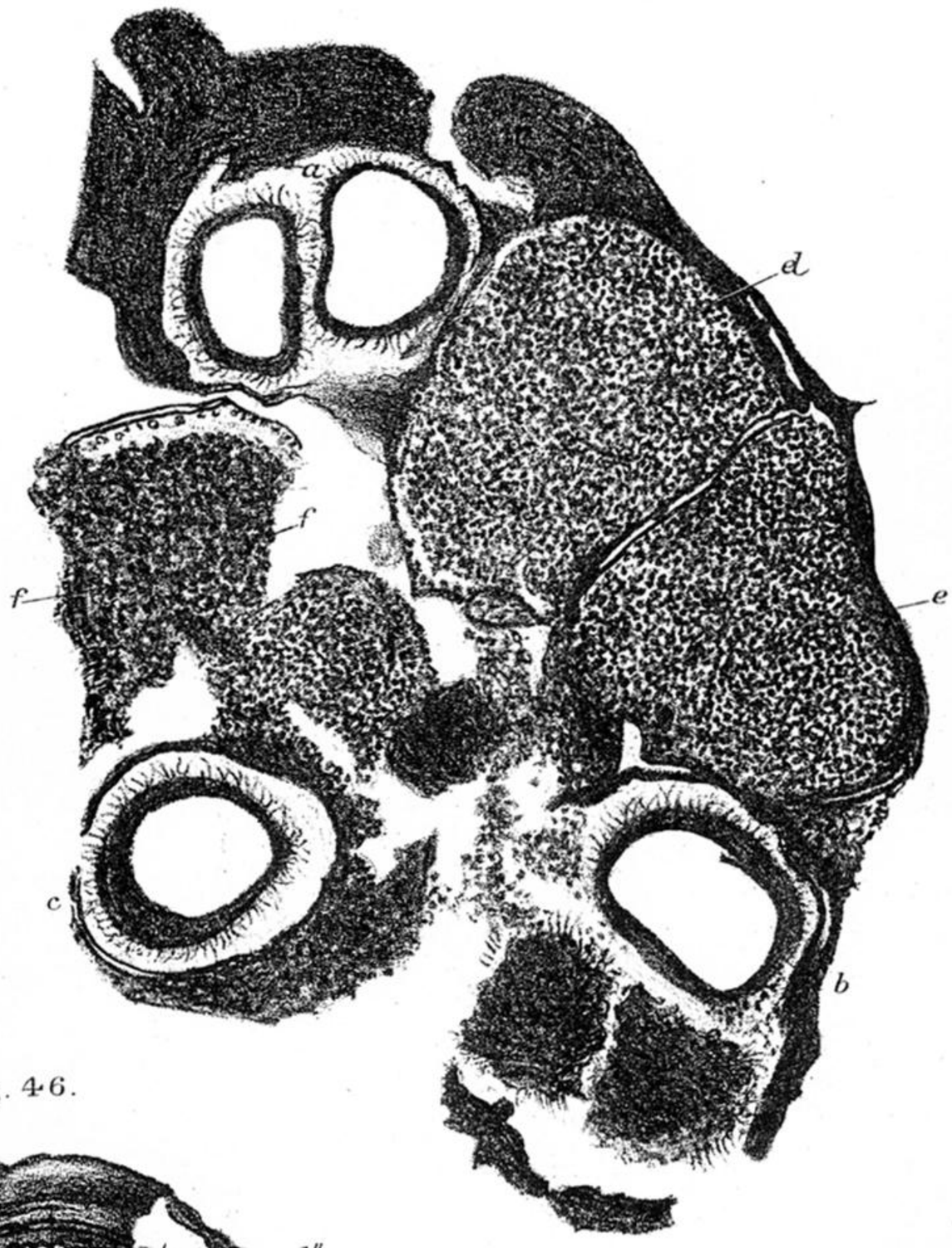

Fig. 46.

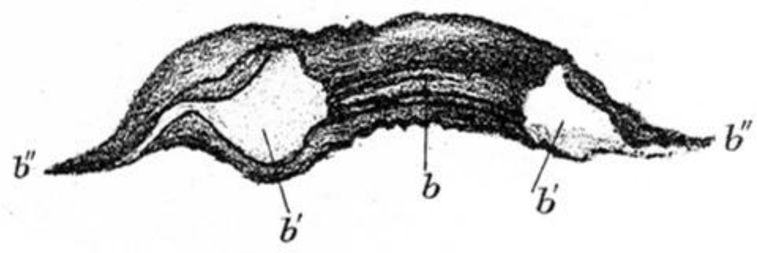

Fig. 49.

Fig. 57.

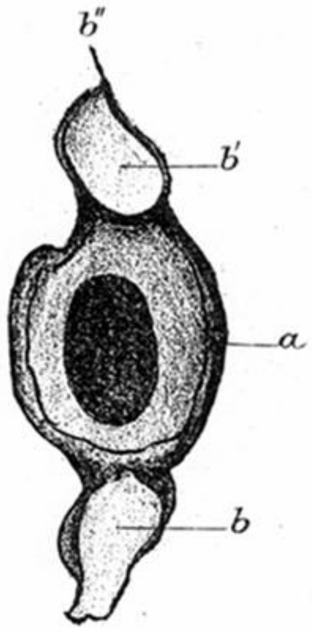

Fig. 47.

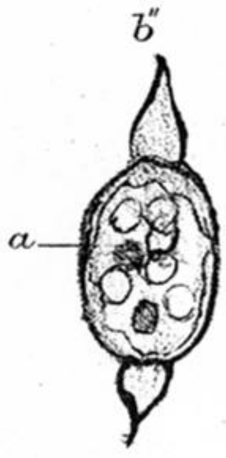

Fig. 48.

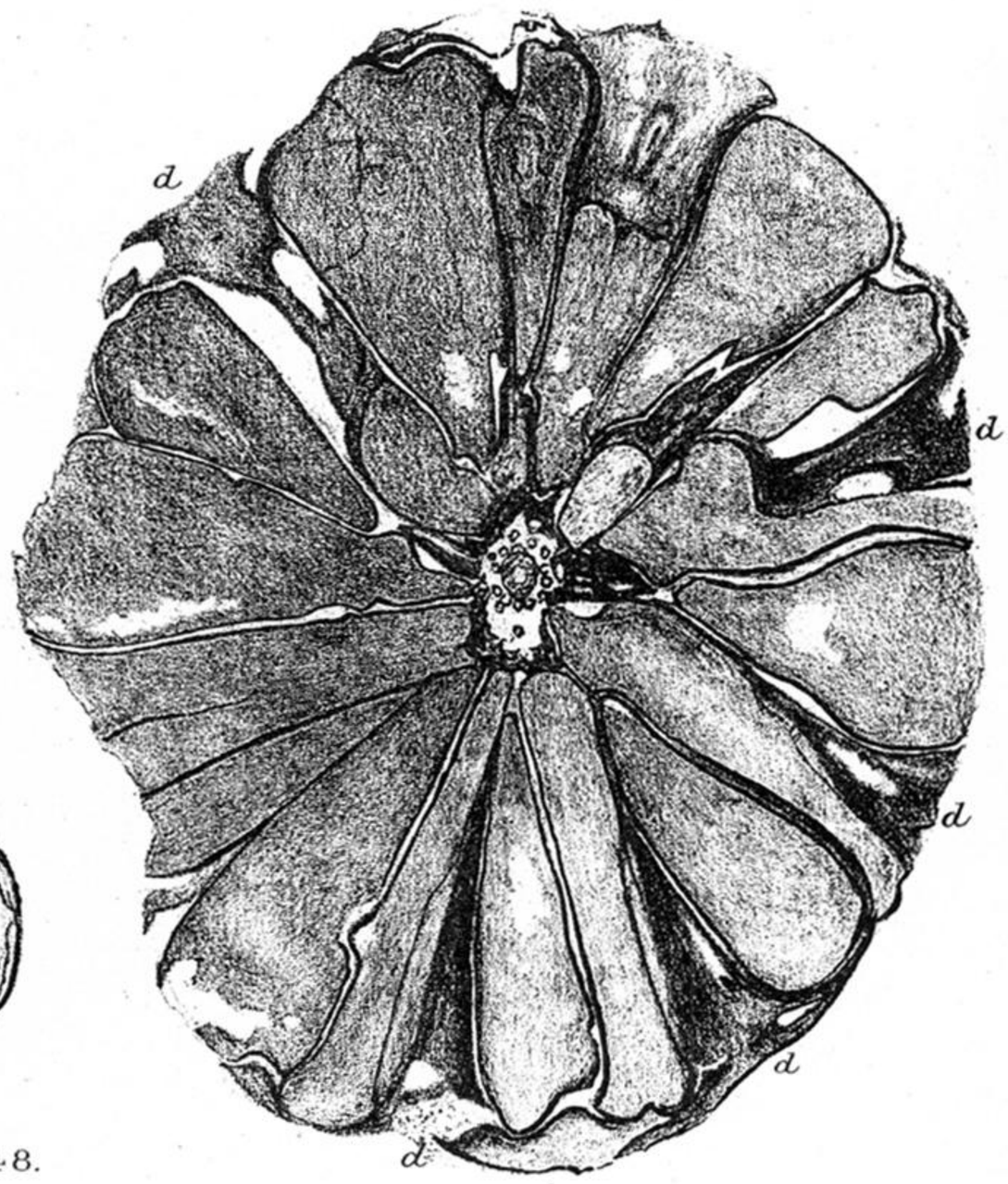

Fig. 58.